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This is one of a series of reports that present methodologies for assessing the potential risks to humans or other organisms from the disposal or reuse of municipal sludge. The sludge management practices addressed by this series include land application practices, distribution and marketing programs, landfilling, incineration and ocean disposal. In particular, these reports provide methods for evaluating potential health and environmental risks from toxic chemicals that may be present in sludge. This document addresses risks from chemicals associated with land application and distribution and marketing of municipal sludge. These proposed risk assessment procedures are designed as tools to assist in the development of regulations for sludge management practices. The procedures are structured to allow calculation of technical criteria for sludge disposal/reuse options based on the potential for adverse health or environmental impacts. The criteria may address management practices (such as site design or process control specifications), limits on sludge disposal rates or limits on toxic chemical concentrations in the sludge.

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DEVELOPMENT OF RISK ASSESSMENT METHODOLOGY FOR LAND APPLICATION AND DISTRIBUTION AND MARKETING OF MUNICIPAL SLUDGE

Environmental Criteria and Assessment Office
Office of Health and Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

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This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

PREFACE

This is one of a series of reports that present methodologies for assessing the potential risks to humans or other organisms from the disposal or reuse of municipal sewage sludge. The sludge management practices addressed by this series include land application practices, distribution and marketing programs, landfilling, incineration and ocean disposal. In particular, these reports provide methods for evaluating potential health and environmental risks from toxic chemicals that may be present in sludge. This document addresses risks from chemicals associated with land application and distribution and marketing of municipal sludge.

These proposed risk assessment procedures are designed as tools to assist in the development of regulations for sludge management practices. The procedures are structured to allow calculation of technical criteria for sludge disposal/reuse options based on the potential for adverse health or environmental impacts. The criteria may address management practices (such as site design or process control specifications), limits on sludge disposal rates or limits on toxic chemical concentrations in the sludge.

The methods for criteria derivation presented in this report have been submitted to the U.S. EPA Office of Water Regulations and Standards (OWRS) to provide scientific background for the development of technical criteria for toxic chemicals in sludge. However, the methods used by OWRS to develop regulations could differ from this guidance in some respects; therefore, the Technical Support Documents provided by OWRS should be consulted for explanation of the regulations.

This document was externally peer reviewed and completed in 1986. Subsequent to further review by the U.S. EPA Science Advisory Board, a revised draft incorporating review comments was produced in 1987. Various scientific and editorial changes, which clarify but do not alter the overall thrust of the document, have been made since that date.

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LIST OF ABBREVIATIONS

αz	Standard deviation of the vertical concentration distance (m)
$\gamma \ell$	Density of sludge liquid (kg/ℓ)
Δt	Elapsed time since the beginning of operation (cannot equal zero)
Δt	Time period over which application is proposed (years)
θ	Available water capacity of soil (dimensionless)
θ	Available volumetric water capacity of the top cm of soil
θe	Effective porosity
θ_{fc}	Field capacity of soil (dimensionless)
θ_{wp}	Wilting point of soil (dimensionless)
υ	Average windspeed (m/sec)
%OM	Percent organic matter
A	Acres tilled/8-hour day
A_a	Sorbed contaminant mass in top centimeter (mg/ha-cm)
ac	Acres
ADI	Acceptable daily intake (mg/kg bw/day)
AMC	Antecedent soil moisture condition
AR	Sludge application rate (t DW/ha)
AR_a	Annual sludge application rate (t DW/ha)
AR_c	Cumulative sludge application rate (t DW/ha)
A_s	Sludge application rate (kg/ha-year)
AWQC	Ambient water quality criteria
b	Slope of matric potential and moisture content plot (dimensionless)
B	Bulk density of soil (g/cm^3)

LIST OF ABBREVIATIONS (cont.)

BB	Background concentration in soil biota (μg/g DW)
BC	Background concentration in crop tissue (μg/g DW)
BCF	Bioconcentration factor (ℓ/kg)
BCF_a	Adjusted BCF (ℓ/kg)
BCF_u	Unadjusted BCF (ℓ/kg)
BI	Background intake of pollutant (mg/day)
BI	Background intake of pollutant from a given exposure route (mg/day)
Bm	Mineral bulk density (g/cm^3)
B_s	Bulk density saturated zone
BS	Background soil concentration of pollutant (μg/g DW)
B_u	Bulk density unsaturated zone
bw	body weight (kg)
C	Concentration of contaminant in sludge/soil mixture (mg/kg)
C	"Cover management" factor (dimensionless)
CAG	Carcinogen Assessment Group
C_c	Compliance point concentration (mg/m^3)
Cd	Cadmium
C_i	Concentration of contaminant in water (mg/ℓ)
C_i test	Receiving water criteria determined from test case (mg/ℓ)
C.E.C.	Cation exchange capacity
C_l	Contaminant concentration in the liquid (mg/ℓ)
Cl_i	Concentration of i in the solution ($mole/m^3$)
CN	SCS runoff curve number (dimensionless)
Cus	Contaminant concentration exiting the unsaturated zone (mg/ℓ)

LIST OF ABBREVIATIONS (cont.)

Cv_i	Concentration of i in air (mass/volume)
C(X)i	Atmospheric concentration (g/m^3)
d	Incorporation depth (cm)
D	Dispersion coefficient
D_a	Dissolved contaminant mass in top centimeter (mg/ha-cm)
DA	Daily dietary consumption of animal tissue food group (g DW/day)
DC	Daily dietary consumption of crop food group (g DW/day)
D&M	Distribution and marketing
D_R	Total storm runoff depth (cm)
ds	Distance to property boundary (m)
D_v	Drainage volume (m^3/m^2-yr)
DW	Dry weight (dried at 105°C until a constant weight is reached)
e	Base of natural logarithms, 2.71828 (unitless)
E	Emission factor (kg/ha)
EDA	Exposure duration adjustment (unitless)
EM	Emission rate (g/sec)
FA	Fraction of animal tissue food group (unitless)
FC	Fraction of crop food group (unitless)
F_i	Contaminant loading rate to the SMA (mg/ha-yr)
FL	Fraction of diet that is adhering soil (g soil DW/g diet DW)
f_{oc}	Organic carbon content (of soil or sludge) (dimensionless)
f_s	Saturated soil moisture content (m^3/m^2)
FS	Fraction of animal diet that is sludge (g soil DW/g diet DW)

LIST OF ABBREVIATIONS (cont.)

ha	Hectare
HCB	Hexachlorobenzene
H_i	Henry's Law constant for i (atm-m^3/mol)
hy	Depth to groundwater (m)
I_a	Air inhalation rate (m^3/day)
I_f	Human consumption of fish (kg/day)
I_p	Acceptable chronic pollutant intake rate (mg/day)
IR	Irrigation (m^3/m^2-yr)
I_s	Soil ingestion rate (g DW/day)
I_w	Total water ingestion rate (ℓ/day)
k	Rate constant for contaminant loss from soil (years^{-1})
k	Particle size multiplier (dimensionless)
k	"Erodibility factor" (metric tons/acre-year-unit 'R')
k_o	Lumped zero-order loss rate constant (mg/ha-year)
k_1	Lumped first-order loss rate constant (yr^{-1})
k_{1D}	First-order loss rate coefficient for degradation (yr^{-1})
k_{1R}	First-order loss rate coefficient for surface runoff losses (yr^{-1})
k_{1i}	First-order loss rate coefficient for infiltration (yr^{-1})
k_2	$F_i - k_o$ (mg/ha-year)
K_d	Soil-water partition coefficient (cm^3/g)
K_{oc}	Organic carbon distribution coefficient for the contaminant (ℓ/kg)
K_{ow}	Octanol-water partition coefficient

LIST OF ABBREVIATIONS (cont.)

k_{sat}	Saturated soil hydraulic conductivity (m/yr)
L	Initial moisture content of sludge (kg/kg)
L_b	Length of buffer strip (m)
L_C	Soil concentration (μg/ℓ DW)
LC_d	Lipid content of dietary seafood (kg/kg)
LC_e	Lipid content of experimental organism (kg/kg)
L_e	Average annual erosional loss delivered to stream (kg/year)
L_o	Average annual erosional loss of contaminant from SMA (kg/year)
LOV	Lacto-ovo-vegetarian
LS	"Topographic or slope/length" factor (dimensionless)
M	Total mass
Ma	Total available mass of contaminant
M_c	Long-term average contamination level in sludge management area (mg/ha)
MEI	Most-exposed individual
Mg	Megagram = 1 metric ton (10^6 g)
MGD	Million gallons/day
M_i	Mass of contaminant lost to surface water (mg/year for long-term case, mg for event case)
M_i event	Total event loading (mg)
M_m	Maximum contaminant mass per area of soil in the SMA (mg/ha)
M_o	Original mass loading of contaminant (mg/ha)
MS	2×10^3 t/ha = assumed mass of soil in upper 15 cm
mt	metric tons
M_t	Total snowmelt depth (cm)

LIST OF ABBREVIATIONS (cont.)

MUSLE	Modified USLE
N	Nitrogen
N	Dry weight concentration of contaminant in sludge
N_i	Contaminant concentration in sludge (mg/kg)
N_i criteria	Sludge concentration criteria (mg/kg)
N_i test	Sludge concentration in test case (mg/kg)
NREL	NIOSH-recommended exposure limit
OHEA	Office of Health and Environmental Assessment
OS	OSHA standard
P	Phosphorus
P	Plateau value (µg/g DW)
P	"Supporting practice" factor (dimensionless)
P	Precipitation (m^3/m^2-yr)
P_a	Total contaminant mass in top centimeter (mg/ha-cm)
PB-PK	Physiologically based pharmacokinetic
PCB	Polychlorinated biphenyl
PFRP	Process to further reduce pathogens
P_i	Partial pressure of i above the solution (atm)
PI	Plateau increment value (µg/g DW)
POTW	Publicly owned treatment works
P_{qt}	Dissolved contaminant loss from SMA (mg/ha)
P_{qt}'	Dissolved contaminant loss from buffer strip (mg/ha)
P_{qt}''	Mass of dissolved contaminant from buffer strip (mg)

LIST OF ABBREVIATIONS (cont.)

P_t	Maximum contaminant level (mg/ha)
P_t	Total pressure in the system (atm)
P_{xt}	Sorbed contaminant loss from SMA (mg/ha)
P_{xt}'	Sorbed contaminant loss from buffer strip (mg/ha)
P_{xt}''	Mass of sorbed contaminant loss from buffer strip (mg)
Q	Volume of runoff (m^3)
Qf	Volumetric flow rate (m^3/sec)
q_1^*	Human cancer potency [$(mg/kg/day)^{-1}$]
q_o	Mass flux input to the unsaturated zone
q_p	Peak runoff rate (m^3/sec)
Q_v	Contaminant flux rate due to volatilization (g/m^2-sec)
r'	Distance from center of source to receptor (m)
R	"Erosivity" factor (year $^{-1}$)
R	Recharge (m^3/m^2-yr)
R_a	Average annual precipitation (cm/yr)
RAC	Reference air concentration (mg/m^3)
R_c	Recharge rate (m/yr)
RC	Reference starting aquifer concentration (mg/ℓ)
Rd	Retardation factor (dimensionless)
RE	Relative effectiveness of exposure (unitless)
RfD	Reference dose (mg/kg/day)
RF	Acceptable mass flux of contaminant (mg/m^2-year)
RFC	Reference feed concentration (μg/g DW)
RIA	Adjusted reference intake (μg/day)
RL	Risk level (unitless)

LIST OF ABBREVIATIONS (cont.)

RLC	Reference soil concentration of pollutant (μg/g DW)
RMCL	Recommended Maximum Contaminant Level
RO	Runoff (m^3/m^2-yr)
R_p	Annual application rate of pollutant in sludge (mg/m^2-yr)
RP	Reference application rate of pollutant (kg/ha)
RP_a	Reference annual application rate of pollutant (kg/ha)
RP_c	Reference cumulative application rate of pollutant (kg/ha)
RPM	Maximum pollutant application rate based on phytotoxicity (kg/ha)
RP_s	Reference single-application rate of pollutant, with no waiting period (kg/ha)
RP_{sT}	Reference single-application rate of pollutant, followed by waiting period or land-use conversion period (kg/ha)
RQ	Reference flux rate due to volatilization (g/m^2-sec)
RSC	Reference sludge concentration (μg/g DW)
R_t	Total storm rainfall depth (cm)
RTI	Reference tissue concentration increment (μg/g DW)
RU	Relative uptake response (unitless)
RWC	Reference water concentration (mg/ℓ)
RX	Reference starting leachate concentration (mg/ℓ)
s	Silt content of soil (%)
S	Water retention parameter (cm)
S	Storage capacity of sludge (kg/kg)
S	Solids content of the sludge (kg/kg)
SC	Sludge concentration (ug/g DW)
S_d	Sediment delivery ratio (dimensionless)

LIST OF ABBREVIATIONS (cont.)

SL	Site length
SMA	Sludge management area (ha)
SRR	Source receptor ratio
SRR	Source-receptor ratio (sec/m)
SW	Site width
t	Metric ton
t	Time (years)
T	Waiting or land-use conversion period (years)
TA	Threshold feed concentration (μg/g DW)
TBI	Total background intake (mg/day)
TC	Tissue concentration (μg/g DW)
TCLP	Toxicity Characteristic Leachate Procedure
TI_S	Highest tissue concentration increment (μg/g DW)
TKN	Total Kjeldahl nitrogen
TL	Plant tissue concentration limit (μg/g DW)
TP	Threshold phytotoxic application rate of the pollutant (kg/ha)
T_r	Storm duration (hours)
T_T	Total travel time across all layers of unsaturated zone (years)
T_u	Steady-state travel time across an unsaturated zone soil layer (years)
UA	Uptake slope of pollutant in animal tissue [μg/g(μg/g)$^{-1}$]
UB	Uptake response slope in soil biota [μg/g(kg/ha)$^{-1}$]
UC	Uptake response slope of pollutant in crops [μg/g(kg/ha)$^{-1}$] or [μg/g(μg/g)$^{-1}$]
USLE	Universal Soil Loss Equation

LIST OF ABBREVIATIONS (cont.)

V	Volume of receiving water (m^3/year for long-term case, m^3 for event case)
V	Vertical term for transport (dimensionless)
V_{ave}	Average velocity across the unsaturated zone (m/year)
W	Width of the buffer zone (cm)
WS	Water content of sludge (kg/kg)
X	Leachate concentration (mg/cm^3)
X	Leachate concentration of contaminants (mg/ℓ)
X_e	Sediment loss rate for long-term case (mt/ha-year)
X_o	Length or width of source (m)
x_s	Sediment loss rate for event case (mt)
X_y	Lateral virtual distance (m)
Y_i	Mole fraction of i in the gas phase (dimensionless)
y^1	Density of the sludge liquid (kg/ℓ)

1. INTRODUCTION AND DESCRIPTION OF GENERAL METHODOLOGIC APPROACH

1.1. PURPOSE AND SCOPE

This is one of a series of reports that present methodologies for assessing the potential risks to humans or other organisms from management practices for the disposal or reuse of municipal sewage sludge. The management practices addressed by this series include land application practices, distribution and marketing programs, landfilling, incineration and ocean disposal. In particular, these reports deal with methods for evaluating potential health and environmental risks from toxic chemicals that may be present in sludge. This document addresses risks from chemicals associated with land application and distribution and marketing of sludge.

These proposed risk assessment procedures are designed as tools to assist in the development of regulations for sludge management practices. The procedures are structured to allow calculation of technical criteria for sludge disposal/reuse options based on the potential for adverse health or environmental impacts. The criteria may address management practices (such as site design or process control specifications), limits on sludge disposal rates or limits on toxic chemical concentrations in the sludge.

The methods for criteria derivation presented in this report are intended to be used by the U.S. EPA Office of Water Regulations and Standards (OWRS) to develop technical criteria for toxic chemicals in sludge. The present document focuses primarily on methods for the development of nationally applicable criteria by OWRS. It is suggested that a user-oriented manual based on these methods be developed for wider use in deriving site-specific criteria for these sludge management practices. Additional uses for the methodology may exist, such as developing guidance for the selection of sludge management options by local authorities, but these uses are not the focus of these documents and will not be discussed.

These documents do not address health risks resulting from the presence of pathogenic organisms in sludge. The U.S. EPA will examine pathogenic risks in a separate risk assessment effort. These documents also do not address potential risks associated with the treatment, handling or storage of sludge; transportation to the point of reuse or disposal; or accidental release.

1.2. DEFINITION AND COMPONENTS OF RISK ASSESSMENT

The National Research Council (NRC, 1983) defines risk assessment as "the characterization of the potential adverse health effects of human exposures to environmental hazards." In this document, the NRC's definition is expanded to include effects of exposures of other organisms as well. By contrast, risk management is defined as "the process of evaluating alternative regulatory actions and selecting among them" through consideration of costs, available technology and other nonrisk factors.

The NRC further defines four components of risk assessment. Hazard identification is defined as "the process of determining whether exposure to an agent can cause an increase in the incidence of a health condition." Dose-response assessment is "the process of characterizing the relation between the dose of an agent ... and the incidence of (the) adverse health effect ...." Exposure assessment is "the process of measuring or estimating the intensity, frequency and duration of ... exposures to an agent currently present or of estimating hypothetical exposures that might arise ...." Risk characterization is "performed by combining the exposure and dose-response assessments" to estimate the likelihood of an effect (NRC, 1983). The U.S. EPA has broadened the definitions of hazard identification and dose-response assessment to include the nature and severity of the toxic effect in addition to the incidence.

Figure 1-1 shows how these components are included in the development of these risk assessment methodologies for sludge management practices. The figure further shows how each methodology may be used to develop technical criteria, and how these criteria could be used or modified by the risk manager to develop regulations and permits.

1.3. RISK ASSESSMENT IN THE METHODOLOGY DEVELOPMENT PROCESS

As illustrated in Figure 1-1, the methodology development process begins by defining the management practice. Even within a given reuse/disposal option, "real world" practices are highly variable, and so a tractable definition must be given as a starting point. As a general rule, this definition should include the types of practices most frequently used. That is, the definition should not be limited to ideal engineering practice but also need not include practices judged to be poor or substandard (unless the latter are widespread). This definition, presented in Chapter 2 of this document, helps to determine the limits of applicability of the methodology and the exposure pathways that may be of concern. However, as also shown in Figure 1-1 and as discussed in Section 1.4., this definition could be modified as the methodology is applied, since the methodology itself will help to define acceptable practice.

1.3.1. Exposure Assessment. The exposure assessment step begins with the identification of pathways of potential exposure. Exposure pathways are migration routes of chemicals from (or within) the disposal/reuse site to a target organism. For those pathways where humans are the target of concern, special consideration is given to individual attributes that influence exposure potential. Individuals will differ widely in consumption and contact patterns relative to contaminated media and, therefore, will also vary widely in their degree of exposure.

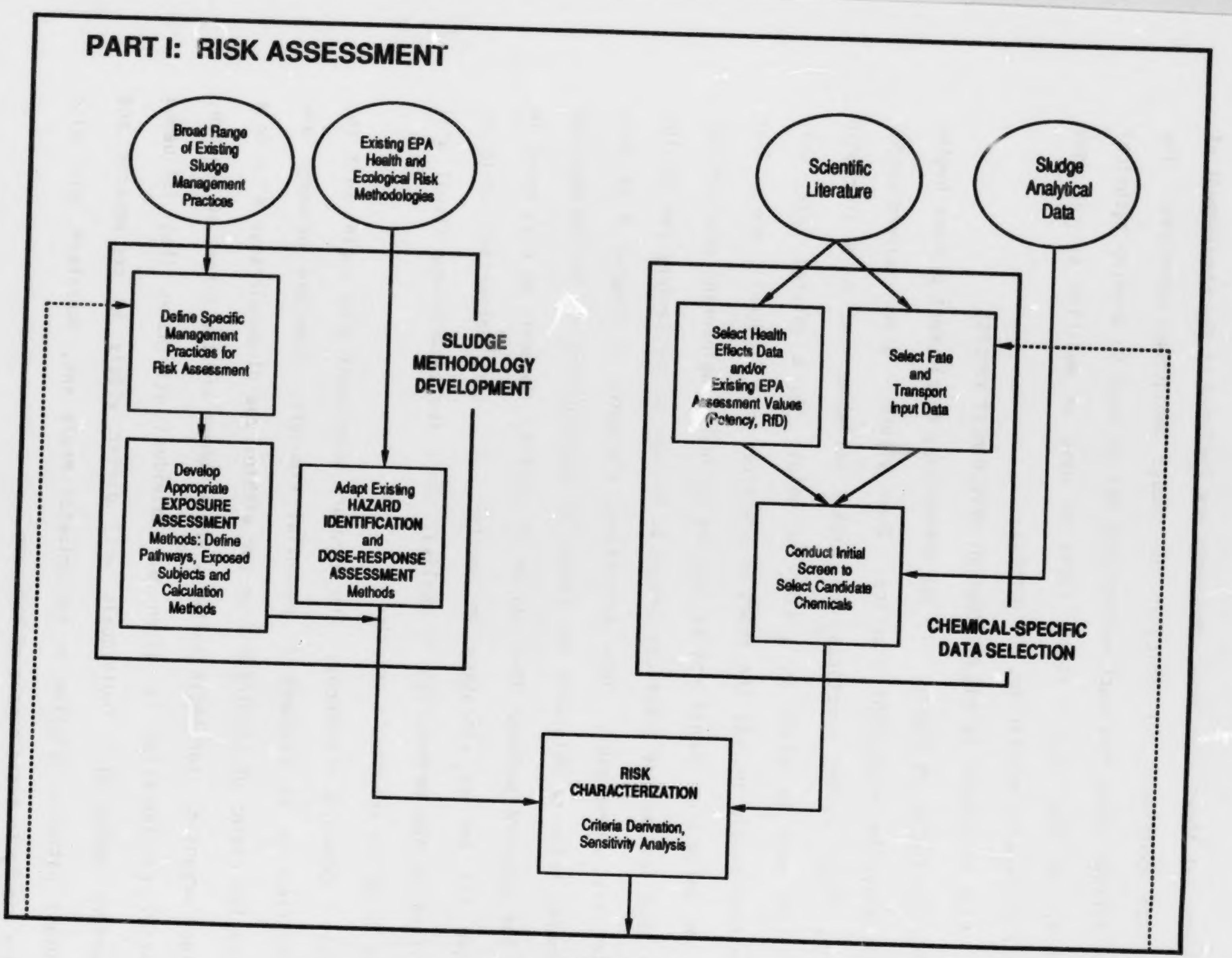
PART I: RISK ASSESSMENT
Broad Range of Existing Sludge Management Practices
Existing EPA Health and Ecological Risk Methodologies
Define Specific Management Practices for Risk Assessment
Develop Appropriate EXPOSURE ASSESSMENT Methods: Define Pathways, Exposed Subjects and Calculation Methods
Adapt Existing HAZARD IDENTIFICATION and DOSE-RESPONSE ASSESSMENT Methods
SLUDGE METHODOLOGY DEVELOPMENT
Scientific Literature
Sludge Analytical Data
Select Health Effects Data and/or Existing EPA Assessment Values (Potency, RfD)
Select Fate and Transport Input Data
Conduct Initial Screen to Select Candidate Chemicals
CHEMICAL-SPECIFIC DATA SELECTION
RISK CHARACTERIZATION
Criteria Derivation, Sensitivity Analysis

FIGURE 1-1

Relationship of Risk Assessment Methodology to Other Components of Regulation Development for Sewage Sludge Reuse/Disposal Options

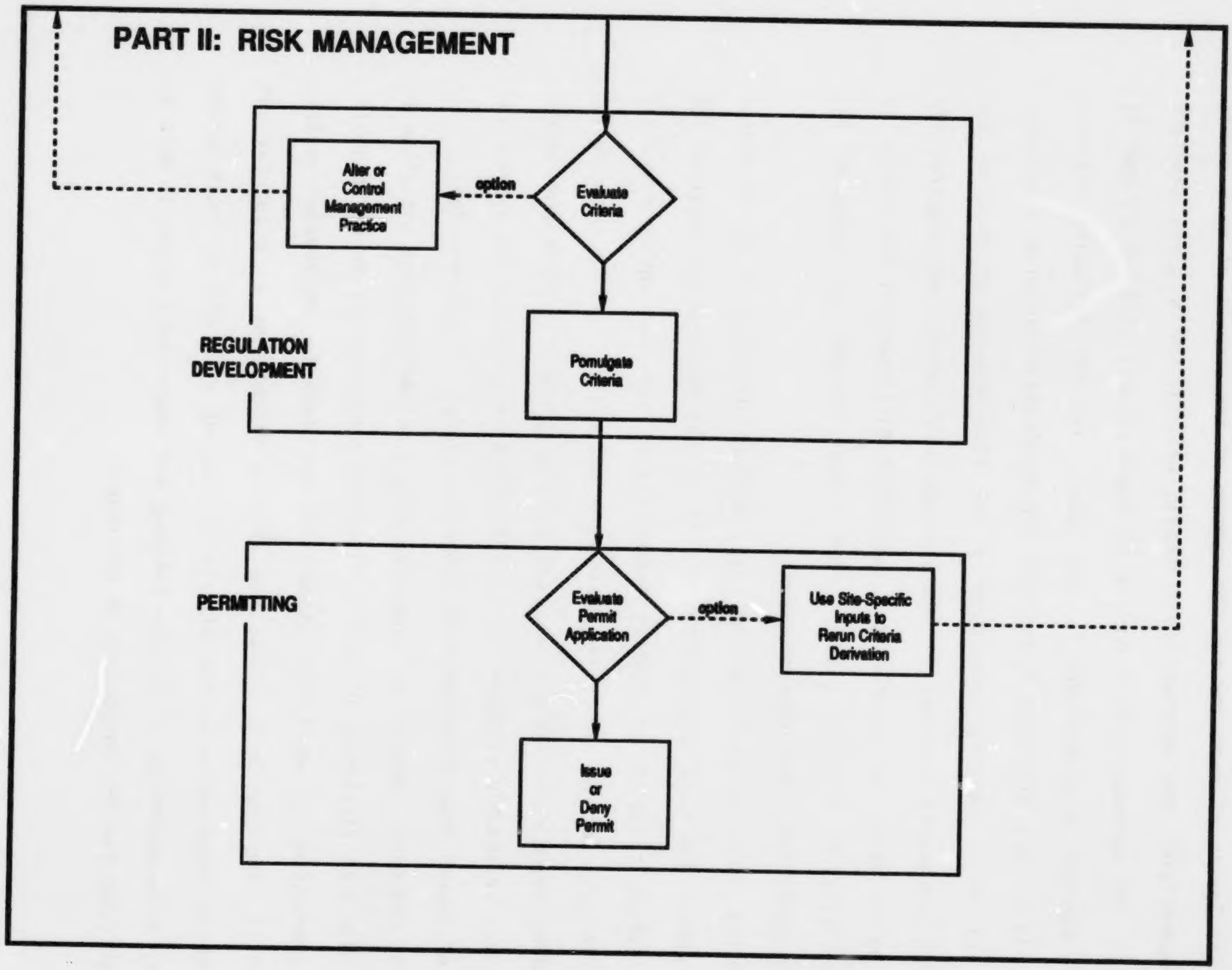
PART II: RISK MANAGEMENT
REGULATION DEVELOPMENT
Evaluate Criteria
option
Alter or Control Management Practice
Pomulgate Criteria
PERMITTING
Evaluate Permit Application
option
Use Site-Specific Inputs to Rerun Criteria Derivation
Issue or Deny Permit

FIGURE 1-1 (cont.)

An ideal way to assess human exposure is to define the full spectrum of potential levels of exposure and the number of individuals at each level, thus quantifying the exposure distribution profile for a given exposure pathway. The methodologies described in these reports will not attempt to define exposure distributions in most cases, for the following reasons. First, it is very difficult to estimate the total distribution of exposures, since to do so requires knowledge of the distributions of each of the numerous parameters involved in the exposure calculations and requires the modeling of actual or hypothetical population distributions and habits in the vicinity of disposal sites. Such a task exceeds the scope of the present methodology development effort.

Second, while knowledge of the total exposure distribution may be useful for certain types of decision-making, it is not necessarily required for establishing criteria to protect human health and the environment. If criteria are set so as to be reasonably protective of all individuals, including those at greatest risk, then as long as the risk assessment procedures can reasonably estimate the risk to these individuals, the quantification of lesser risks experienced by other individuals is not required.

The drawback, however, of examining only a maximal-exposure situation is that the true likelihood of such a situation occurring may be quite small. The compounding of worst-case assumptions may lead to improbable results. Therefore, the key to effective use of this methodology is a careful and systematic examination of the effects of varying each of the input parameters, using estimates of central tendency and upper-limit values to gain an appreciation for the variability of the result.

Therefore, exposure will be determined for a most-exposed individual, or MEI.* The definition of the MEI will vary with each human exposure pathway. Chapter 3 of this document will enumerate the exposure pathways and will define the MEI in qualitative terms; for example, for the "home garden" scenario, the MEI is a person producing much of his or her own crops on sludge-amended soil. The MEI will not be quantitatively defined in this chapter, but relevant information that allows the user to do so (such as available data on the ranges of crop consumption rates) will be provided in later chapters. For exposure pathways concerning organisms other than humans, the term "MEI" is not applied, but conservative assumptions are still made regarding the degree of exposure. The remaining chapters (Chapters 4-8 in this document) explain the calculation methods and data requirements for conducting the risk assessments for each pathway.

1.3.2. Hazard Identification and Dose-Response Assessment. To determine the allowable exposure level for a given contaminant, the hazard identification and dose-response assessment steps must be carried out. For human health effects, these procedures already are fairly well established in the Agency (although they still require improvement, and specific assessments for many chemicals remain problematic). Hazard identification in this case consists first of all of determining whether or not a chemical should be treated as a human carcinogen. Procedures for weighing evidence of carcinogenicity have been published in the Federal Register (1986a) and are further discussed in later sections of this document. If a chemical is treated as carcinogenic, dose-response assessment would then include the use of Agency-accepted potency values. If none are available, cancer risk estimation procedures published by the Agency (Federal Register, 1986a) would be used to determine potency.

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*The definition of the MEI does not include workers exposed in the production, treatment, handling or transportation of sludge. This methodology is geared toward protection of the general public and the environment. It is assumed that workers can be required to use special measures or equipment to minimize their exposure to sludge-borne contaminants. Agricultural workers, however, might best be considered members of the general public since the use of sludge may not be integral to their occupation.

If a chemical is not carcinogenic, hazard identification and dose-response assessment normally consist of identifying the critical systemic effect, which is the adverse effect occurring at the lowest dose, and the reference dose (RfD), which is "the daily exposure ... that is likely to be without appreciable risk of deleterious effects during a lifetime" (U.S. EPA, 1987a). Further description and procedures for deriving RfDs are published in U.S. EPA (1987a).

For certain disposal options, effects on other organisms are of concern. In these cases, existing Agency methodologies have been used where available. For example, existing guidelines for deriving ambient water quality criteria (AWQC) (U.S. EPA, 1984c) are used to determine levels for protecting aquatic life. Where effects on terrestrial species are of concern, there are no existing Agency guidelines, but suggested procedures for identifying adverse effects (hazard identification) and threshold levels (dose-response assessment) are provided.

1.3.3. **Risk Characterization.** Risk characterization consists of combining the exposure and dose-response assessment procedures to derive criteria. Risk assessments ordinarily proceed from source to receptor. That is, the source, or disposal/reuse practice, is first characterized and contaminant movement away from the source is then modeled to estimate the degree of exposure to the receptor, or MEI. Health effects for humans or other organisms are then predicted based on the estimated exposure. The calculation of criteria, however, involves a reversal of this process. That is, an allowable exposure, or an exposure that is not necessarily allowable but corresponds to a given level of risk, is defined based on health effects data, as specified above. Based on this exposure level, the transport calculations are either operated in reverse or performed iteratively to determine the corresponding source definition. In this case, the resulting source definition is a combination of management practices and sludge characteristics, which together constitute the criteria. These steps are carried out on a chemical-by-chemical basis, and criteria values are derived for each chemical assessed and each exposure pathway. An example illustrating how these calculations may be carried out is provided in this document for each pathway assessed. However, as indicated by Figure 1-1, the compilation of data on specific chemicals to be used as inputs to the methodology is a process separate from methodology development. Health effects data for individual chemicals must be collected from the scientific literature. In many cases, the U.S. EPA has already published approved values for cancer potency or RfD. Data pertinent to a chemical's fate and transport characteristics, such as solubility, partition coefficient, bioconcentration factor or environmental half-life, must also be selected from the literature. In some cases, data for particular health or fate parameters were gathered for a variety of chemicals in the process of developing the methodology. Where this was done, the information may appear as an appendix. In most cases, however, such information does not appear in the methodology document and must be gathered as a separate effort.

Once these data have been selected, even on a preliminary basis, it may be useful to carry out a rough screening exercise, using these data plus information on occurrence in sludges, to set priorities for risk characterization. Screening could reveal that certain pollutants are unlikely to pose any risk, or that data gaps exist that preclude more detailed characterization of risk. Methods for carrying out such a screening procedure will not be discussed in this document.

Following chemical-specific data selection, risk characterization or criteria derivation may be conducted. The values derived as limits on sludge concentration or disposal rate, together with the management practice definitions, will constitute the criteria. When calculating the numerical limits, it is advisable to vary each of the input values used over its typical or plausible range to determine the sensitivity of the result to the value selected. Sensitivity analysis helps to give a more complete picture of the potential variability surrounding the result.

1.4. POTENTIAL USES OF THE METHODOLOGY IN RISK MANAGEMENT

The results of the risk characterization step can then be used as inputs for the risk management process, as shown in Part II of Figure 1-1. Although this document does not specify how risk management should be conducted, some potential uses of the methodology in the risk management process are briefly described here. These optional steps are shown as dashed lines in Figure 1-1.

As suggested by the National Research Council (NRC, 1983), a risk manager may evalute the feasibility of a set of criteria values based on consideration of costs, available technology and other nonrisk factors. If it is felt that certain chemical concentrations specified by the calculations would be too difficult or costly to achieve, the management practice definition could be modified by imposing controls or restrictions. For example, requirement of subsurface injection or waiting periods before grazing is permitted on sludge-applied lands could result in higher permissible concentrations for some pollutants. The same degree of protection would still be achieved.

Following promulgation of the criteria, it may also be possible to evaluate sludge reuse or disposal practices on a site-specific basis, using locally applicable data to rerun the criteria calculations. Criteria could then be varied to reflect local conditions. Thus, the risk manager can use the methodology as a tool to develop and fine-tune the criteria.

1.5. LIMITATIONS OF THE METHODOLOGY

Limitations of the calculation methods for each pathway are given in the text and in tabular form in the chapters where calculation methods are presented. However, certain limitations common to all of the methods are stated here.

Municipal sludges are highly variable mixtures of residuals and by-products of the wastewater treatment process. Chemical interactions could affect the fate, transport and toxicity of individual components, and risk from the whole mixture may be greater than that of any single component. At present, these methodologies treat each chemical as though it acts in isolation from all the others. It should be noted that EPA's mixture risk assessment guidelines (Federal Register, 1986b) caution that a great deal of dose-response information is required before a risk assessment may be quantitatively modified to account for toxic interactions. Future revisions to these documents to include consideration of interactions will most likely be limited to qualitative discussion of such interactions.

Transformation of chemicals occurring during the disposal (including combustion) practice or following release may result in exposure to chemicals other than those originally found in the sludge. In many cases these assessment procedures may not adequately characterize risks from these transformation products.

In addition, these methodologies compartmentalize risks according to separate exposure pathways. The use of an MEI approach, which focuses on the most highly exposed individuals for each pathway, reduces the likelihood that any single individual would simultaneously receive such exposures by more than one pathway, and therefore the addition of doses or risks across pathways is not usually recommended. However, it is possible that risk could be underestimated in a small number of instances.

Finally, the methodologies look at exposed organisms in isolation. Population-level or ecosystem-level effects that could result from a reuse or disposal practice might not be predictable by this approach.

2. DEFINITION OF MANAGEMENT PRACTICES

2.1. INTRODUCTION

Municipal sludge production was estimated at 6.84 million metric tons dry weight* (t DW) in 1982. By the year 2000, production is expected to nearly double (12 million t DW/year). A survey of 6.5% of the U.S. treatment plants in 1982 revealed the distribution between disposal/reuse options presented in Table 2-1. Land application and distribution and marketing (D&M) practices accounted for 2.87 t DW, or 42% of the total (Booz Allen and Hamilton, 1982; U.S. EPA, 1983b). If the relevant distribution among alternatives remains constant, it would be expected that 5.0 million t DW of municipal sludge will be applied to land annually in the year 2000.

This chapter will briefly define the many practices included within the land application and D&M management options. A detailed description of the process design for each of these practices will not be given here; additional information may be found in U.S. EPA publications such as the Process Design Manual for Land Application of Municipal Sludge (U.S. EPA, 1983b) and Composting of Municipal Wastewater Sludges (U.S. EPA, 1985b). The definitions given here will be limited to certain aspects that help to outline the scope for the risk assessment methods that follow. These definitions include stated assumptions or requirements regarding the forms that these practices may take. Some of these assumptions or requirements allude to the potential exposure pathways from each practice. The pathways themselves will be more fully discussed in Chapter 3.

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*Throughout this document, the term "dry weight" should be considered to mean dried at 105°C until a constant weight is obtained. Analysis of a particular contaminant may be done on a wet weight or as is basis, but the results should be expressed on a dry weight basis.

TABLE 2-1

Distribution of Sludges Between Disposal/Reuse Alternatives[a,b]

Alternative	Million Dry Metric Tons (10^6t DW)	Percent
Incineration	1.85	27
Land application		
Human food chain crops	0.82	12
Nonfood chain crops	0.82	12
Distribution and marketing	1.23	18
Landfilling	1.03	15
Ocean disposal	0.27	4
Other[c]	0.82	12
TOTAL	6.84	100

[a] Source: Booz Allen and Hamilton, 1982; U.S. EPA, 1983b

[b] Based on a 1982 random survey of 1011 treatment plants (6.5% of total number of plants)

[c] Other includes lagoons and impoundments that constitute storage rather than disposal. Ultimately, these facilities will be closed as landfills or the sludge will be exhumed and sent for disposal by one of the alternative means. There are no data at this time from which one can quantitatively ascertain the distribution of sludge volumes among the ultimate disposal alternatives.

2.2. LAND APPLICATION PRACTICES

Land application refers to the distribution of sludge on or just below the soil surface where it is employed as a fertilizer or soil conditioner to grow human food-chain and non-food-chain crops or to utilize the land as a sludge treatment system. Potentially adverse environmental or animal and human health effects can be prevented by establishing acceptable pollutant concentrations, application rates, good management practices (such as physical barriers or record-keeping requirements) or, in certain cases, land deed stipulations to manage conversion to uses that could have greater potential for exposure. Four major designations for land application are listed below:

Agricultural utilization
Forest land utilization
Drastically disturbed land utilization
Dedicated land disposal site

These options are not mutually exclusive; there is an overlap in several of their characteristics. However, for the purpose of regulating the use of sludge in each option, it is necessary to clearly define each practice and differentiate between them.

2.2.1. Agricultural Utilization. Agricultural use of sludge includes sludge application to land used for a wide range of crops including grains, animal feeds and non-food-chain crops. The objective of this practice is to improve the soil-conditioning properties and nutrient status, and to increase crop production. This practice is probably of most concern because it may involve incorporation of the pollutant in the human food chain. The following assumptions or requirements will be made regarding this practice.

2.2.1.1. ASSUMPTIONS --

1. Human food-chain and non-food-chain crops are expected to be grown where this practice is utilized.

2. Work practices that reduce the possibility of offsite contamination, such as washing of application equipment, will be assumed.

3. Agricultural lands have a potential of being converted to residential usage after sludge application to crops.

2.2.1.2. REQUIREMENTS OR POTENTIAL REQUIREMENTS --

1. Sludge will be applied at no greater than agronomic rates, defined as annual rate at which nitrogen (N) or phosphorus (P) supplied by the sludge does not exceed the annual N or P requirement of the crop. The range varies from 2 to 35 t DW/hectare (ha) for most sludges, but may be as high as 70 t DW/ha for some composts. (It should be noted that P often is more limiting than N.)

2. A waiting period after application may safely allow higher application rates of sludge because of chemical immobilization or degradation of constituents. Therefore, the need for a waiting period before planting crops will be evaluated, as will a waiting period before grazing of treated pasture land.

3. The criteria derivation procedures given herein will evaluate the need for differences in criteria based on soil pH.

4. The criteria derivation procedures given herein will evaluate the need for criteria based on varying certain physical characteristics of potential sites. These characteristics include slope, depth to water table, permeability, infiltration and proximity to surface water.

5. All publicly owned treatment works (POTWs) will be required to analyze the chemical composition of sludge using proper quality assurance procedures.

6. Records on the locations and amounts of sludge application and a copy of the POTW's analysis of sludge composition will be maintained by the POTW.

7. Incorporation of sludge into the soil (either by injection or tilling) is required before crops are planted for human consumption. The criteria derivation procedures given herein will evaluate the need for requiring soil-incorporation before other uses (such as use for pasture or other crops).

2.2.2. Forest Land Utilization. Application to forest lands decreases the concern over direct entry of the pollutant into the human food chain and thus has an advantage over agricultural utilization. However, forest lands may be converted to agricultural or residential use, so protection of these lands for their potential future use is generally accepted. The following assumptions and requirements will be made regarding this practice.

2.2.2.1. ASSUMPTIONS --

1. The majority of plants grown where this practice is utilized are not in the human food chain. The only human food chain crops, for example, might be mushrooms and wild berries consumed by humans or plants consumed by wildlife, such as deer or birds.

2. Sludge may be applied at levels higher than the agronomic rates. It has been shown that forest surface litter layers have a comparatively high storage capacity; therefore, higher application rates than those allowed on agricultural soils may be applied in many instances without changing the degree of protection from nitrate leaching to sensitive aquifers. The range may vary from 10 to 100 t DW/ha every 3-5 years.

3. Work practices that reduce the possibility of offsite contamination, such as washing of application equipment, will be assumed.

4. Forest application of sludge will occur at different stages of plant growth. Therefore, application is not limited by season, except that application on frozen land is not permitted.

5. Forest lands have a potential of being converted to agricultural or residential use after sludge application. However, such conversion would not be immediate; an elapsed time or conversion period following sludge application may be assumed.

2.2.2.2. REQUIREMENTS OR POTENTIAL REQUIREMENTS --

1. Public access is restricted by signs adjacent to public roads. The signs prohibit use of the area or its products for human food consumption.

2. The public will be restricted to a given distance downwind during spray application.

3. The criteria derivation procedures given herein will evaluate the need for criteria based on varying certain characteristics of potential sites. These characteristics include slope, depth to water table, permeability, infiltration and proximity to surface water.

4. The POTW will be required to analyze the chemical composition of sludge using proper quality assurance procedures.

5. Records on the locations and amounts of sludge application and a copy of the POTW's analysis of sludge composition will be maintained by the POTW.

6. Sludge application on frozen land is not permitted.

2.2.3. Drastically Disturbed Land Utilization. Sludge application to drastically disturbed lands is often referred to as land reclamation. In this practice, barren lands are treated to improve site aesthetics and utility through regrowth of vegetation and landscaping. These barren lands can be a result of mines, quarries or sand and gravel pits. They may have problems such as acid runoff, high erosion rates, low nutrient levels and high toxic levels of polutants. All these characteristics can be improved by sludge application if the site and sludge use are properly managed. In these practices, the amounts of sludge applied can be drastically different than those applied for agricultural and forest use. The following is a list of assumptions and requirements that will be made for this practice.

2.2.3.1. ASSUMPTIONS --

1. Because sludge application is expected to drastically enhance or to be a substitute for topsoil, a much larger application of sludge may be necessary to establish vegetation and improve the physical properties of the surface material. It is often applied to disturbed land in a one-time, large application, but repeated applications may also occur.

2. Work practices that reduce the possibility of offsite contamination, such as washing of application equipment, will be assumed.

3. Disturbed lands have a potential for being used as agricultural or residential lands following reclamation with sludge. Unless the same restrictions that protect these latter uses are applied to reclamation practices, it is assumed that the land will be tested and evaluated to determine its suitability before it is used for agriculture or residences.

4. Land conversion to its intended use would not be immediate; an elapsed time or conversion period following sludge application may be assumed.

2.2.3.2. REQUIREMENTS OR POTENTIAL REQUIREMENTS --

1. The criteria derivation procedures given herein will evaluate the need for criteria based on varying certain characteristics of potential sites. These characteristics include slope, depth to water table, permeability, infiltration and proximity to surface water.

2. The POTW will be required to analyze the chemical composition of sludge using proper quality assurance procedures.

3. Records on the locations and amounts of sludge application and a copy of the POTW's analysis of sludge composition will be maintained by the POTW.

4. Public access is restricted by signs adjacent to public roads. The signs prohibit use of the area or its products for human consumption.

2.2.4. Dedicated Land Disposal Site. The primary purpose of the site is long-term disposal of sludge. The objective is to employ soil as a treatment system by allowing soil to retain the metals and allowing sunlight, microorganisms and chemical processes to degrade organic matter in the sludge. The following is a list of assumptions and requirements for this disposal practice.

2.2.4.1. ASSUMPTIONS --

1. It is assumed that any crops produced on "dedicated land" are unfit for human consumption (or for consumption by animals that will be consumed by humans). Crops produced on dedicated sites may be utilized for human consumption or for consumption by animals that will be consumed by humans only if their compositon is found to be acceptable. Also, feed crops for animals not consumed by humans may be grown if they are analyzed and evaluated before use.

2. It is assumed that these sites are totally controlled by a responsible governmental agency.

2.2.4.2. REQUIREMENTS OR POTENTIAL REQUIREMENTS --

1. Work practices that reduce the possibility of offsite contamination, such as washing of application equipment, will be required.
2. Public access is restricted by signs and fences adjacent to public roads. The signs prohibit use of the area or its products.
3. The criteria derivation procedures given herein will evaluate the need for criteria based on varying certain characteristics of potential sites. These characteristics include slope, depth to water table, permeability, infiltration and proximity to surface water.
4. The POTW will be required to analyze the chemical composition of sludge using proper quality assurance procedures.
5. Records on the locations and amounts of sludge application and a copy of the POTW's measurement of sludge composition will be maintained by the POTW.
6. Future property owners are notified by a stipulation in the land record or property deed that states that the property has received solid waste at high contaminant application rates and that unless soil analyses show an absence of hazard, human food-chain crops should not be grown and young children should not be permitted access to the site because of possible health hazards.
7. It is assumed that closure and hazard evaluation procedures will be established and will be required before sale of a site or use for another purpose.

2.2.5. Summary. There are differences among land uses and sludge application practices. The potential changes in land use may blur some of these distinctions where risk assessments are concerned. Forest, agricultural and reclaimed lands can potentially become agricultural or residential. For agricultural use, sludge application is limited to agronomic rates, whereas for forest and reclamation uses it typically is higher. A second difference is that for forest use, there will be restricted use of the forest and its products for human consumption, and a conversion period is assumed before agricultural use occurs. Third, an assumption for forest and reclamation usages is that there will be a conversion period before agricultural use. Conversion periods before residential use are also assumed for nonresidential lands. A critical difference between forest, agricultural and land reclamation use vs. dedicated-land disposal is that in the latter, conversion of land use is not assumed. Therefore, if a dedicated site is to be converted, its suitability for the intended use needs to be carefully evaluated. This evaluation is ensured by the requirement of a warning statement in the land record or property deed.

2.3. DISTRIBUTION AND MARKETING PRACTICES

Distribution and marketing (D&M) refers to the give-away or sale of sludge or sludge products either in bulk or bagged to the public, commercial growers or local governments for use as fertilizers or soil conditioners for food- and non-food-chain vegetation. Potentially adverse environmental or animal and human health effects can be prevented by establishing acceptable pollutant concentrations, application rates and labeling requirements. Establishing and monitoring of good management practices or record-keeping requirements by users are not feasible using this option.

Usually, in this practice the sludge has undergone some method of treatment to either dewater or reduce the volume of sludge before distribution. Sludge treatment before D&M varies among POTWs and may include, but is not limited, to the following:

Aerobic digestion
Anaerobic digestion
Heat drying/treatment
Mechanical dewatering
Composting
Air drying

In addition, humus material or nutrient additives may be blended with the sludge to increase its fertilizer or soil-conditioning value.

Distribution and marketing programs currently practiced by POTWs range from simple give-away programs, in which the local citizen picks up sludge that has been stockpiled at the treatment plant, to detailed marketing programs, such as the distribution of a bagged product to retail and wholesale outlets. The various end-uses associated with these programs can be classified as shown below:

Residential	Commercial	Institutional
Gardens Lawns Landscaping	Nurseries Turf farms Golf courses Other horticultural uses	Parks and recreation areas Cemeteries Roadsides School grounds and other public lands

The end-use and demand for sludge-derived D&M products is based upon the characteristics of the sludge, which include nutrient content (concentration and availability of nitrogen and phosphorus) and physical nature (moisture content and consistency).

These end-uses of D&M sludge products determine the populations and environments initially exposed to contaminants that may be present in the product. For instance, expected human exposure to sludge-borne contaminants would be much higher for sludge applied to home gardens than for sludge applied to cemeteries or roadsides. Sludge ingestion by children by either hand-to-mouth play or pica would be a possibility for the residential settings, but is less likely for commercial or institutional applications.

In addition to end-use of the D&M sludge product, however, future use of the land to which the product has been applied is also important in determining potential risk. Therefore, the potential for land-use conversion must also be considered.

The following assumptions are made for this option.

2.3.1. Assumptions.

1. Both food-chain and non-food-chain crops are grown using D&M sludge products.
2. Few, if any, site controls or record-keeping requirements are employed.
3. Animals consumed by humans are not expected to forage on crops grown on sludge-amended soil in the residential, commercial or institutional D&M end-uses. Applications to parks or recreational areas where hunting is permitted would constitute forest land utilization rather than D&M.
4. All lands to which D&M sludge products are applied, with the exception of roadsides, are considered to have the potential for conversion to residential use, including use for home gardens. In many cases, however, such conversion would not be immediate; an elapsed time or conversion period following sludge application may be assumed.

2.3.2. Requirements or Potential Requirements.

1. A printed handout (in the case of bulk distribution) and a label (for bagged products) will provide information on essential plant nutrient content, instructions for proper use on different plant types and loading rates (such as number of square feet per bag, ratio of sludge to soil in sludge-soil mixture) that should not be exceeded.

3. EXPOSURE PATHWAYS AND MOST-EXPOSED INDIVIDUALS (MEIs)

Humans or other organisms may be exposed to the contaminants in land-applied sludge by a variety of pathways. The relative importance of a given pathway is influenced by the type of land application practice employed and by potential future uses of the land receiving sludge. The definitions, assumptions and requirements stated for these practices in Chapter 2 will be used here to identify those pathways that may be of concern for a given practice and those that can be eliminated a priori.

If a particular exposure pathway is stated here to be of concern for a given management practice, this means that the assessment methods for that pathway, described in the latter chapters of this document, should be used to determine whether criteria will be required. It does not necessarily mean that criteria will be needed.

For each exposure pathway, it is important to identify the most-exposed individual, or MEI. Occupational exposures (other than of agricultural workers) are not considered, as discussed in Chapter 1. While many individuals of the general public may be exposed to a varying degree, the MEI is that individual who would be expected to experience the greatest risk and, therefore, requires the greatest protection. The MEI is a hypothetical (not actual) individual, but care should be taken that the definition be realistic. The definition depends on many of the assumptions and requirements made concerning each management practice listed in Chapter 2. The pathways and MEIs will be described qualitatively in this chapter and quantitatively in the following chapters where criteria calculation methods are given.

The upper portion of Table 3-1 summarizes the selection of pathways that are relevant to each land application or distribution and marketing (D&M) practice, according to either current or future land use. Some judgment was required in making these selections, since practice definitions may vary or overlap. The pathways selected are those judged to have a reasonable probability of becoming important for each management practice.

The resulting matrix of pathways and practices is complex, reflecting the complexity of sludge utilization practices and of the environment. To provide a more manageable framework for conducting risk assessments, a reduced number of practice categories is suggested, as shown in the lower portion of Table 3-1. For example, since all land application sites other than those dedicated to sludge disposal are considered to have a potential for eventual conversion to agricultural lands or residential gardens, all 13 pathways may apply either currently or in the future. Except for roadsides, all lands to which D&M sludge products may be applied are also considered to have the potential for conversion to residential use (see Section 2.3.1.). Therefore, highway landscaping has been singled out from all other D&M uses for special treatment. Any other D&M later shown to fit this criterion could be handled in a similar fashion, however.

A future exposure may entail lower risk than a current one, since some contaminants applied in sludge may be lost over the time period elapsed before land-use conversion. For simplicity, the suggested categorization ignores the conversion period. However, methods to account for the conversion period in criteria calculations are provided in Chapter 4 and can be used if desired.

TABLE 3-1

Exposure Pathways Applicable to Current or Future Land Use

Sludge Management Practices[b]	Exposure Pathways[a] 1	2	3	4	5	6	7	8	9	10	11	12	13
Land Application (LA)													
Agricultural use	X[c]	X	X	X	X	X	X	X	X	X	X	X	X
Forest use	X	X	X	X	X	X	X	X	X	X	X	X	X
Land reclamation	X	X	X	X	X	X	X	X	X	X	X	X	X
Dedicated-land disposal	–	–	–	–	–	–	–	–	X	X	X	X	X
Distribution and Marketing (D&M)													
Residential use (garden, lawn, landscaping)	X	X	–	–	X	X	X	X	X	–	X	X	–
Nurseries-pots (ornamental)	X	X	–	–	X	X	X	X	X	–	X	X	–
Nurseries-field (ornamental); turf farms	X	X	–	–	X	X	X	X	X	X	X	X	–
Hothouse (pot) crop production	X	X	–	–	X	X	X	X	X	–	X	X	–
Truck farming	X	X	–	–	X	X	X	X	X	X	X	X	–
Park and recreational areas (nonforest)	X	X	–	–	X	X	X	X	X	–	X	X	–
Golf courses, cemeteries, school grounds and other public lands	X	X	–	–	X	X	X	X	X	–	X	X	–
Highway landscaping	–	–	–	–	–	–	X	X	X	X	X	X	–
Suggested Categories for Risk Assessment													
All LA practices except dedicated-land disposal	X	X	X	X	X	X	X	X	X	X	X	X	X
Dedicated-land disposal	–	–	–	–	–	–	–	–	X	X	X	X	X
All D&M practices except highway landscaping	X	X	–	–	X	X	X	X	X	X	X	X	–
Highway landscaping	–	–	–	–	–	–	X	X	X	X	X	X	–

[a]

Exposure Pathways	Sections in Text	
Terrestrial Food Chain (1-9)		
1. Sludge-Soil-Plant-Human Toxicity	3.1.	4.
2. Sludge-Human Toxicity ("Soil Ingestion")	3.1.1.	4.2.
3. Sludge-Soil-Plant-Animal-Human Toxicity	3.1.2.	4.3.
4. Sludge-Animal (Direct Ingestion)-Human Toxicity	3.1.3.	4.4.
5. Sludge-Soil-Plant-Animal Toxicity	3.1.3.	4.4.
6. Sludge-Animal Toxicity (Direct Ingestion)	3.1.4.	4.5.
7. Sludge-Soil-Plant Toxicity	3.1.4.	4.5.
8. Sludge-Soil-Soil Biota Toxicity	3.1.5.	4.6.
9. Sludge-Soil-Soil Biota-Predator Toxicity	3.1.6.	4.7.
10. Particulate Resuspension	3.1.6.	4.7.
11. Surface Runoff	3.2.	5.
12. Groundwater	3.3.	6.
13. Vaporization	3.4.	7.
	3.5.	8.

[b] For definition of sludge management practices see Chapter 2.

[c] X indicates exposure pathways relevant to either current or future land use. See text.

3.1. TERRESTRIAL FOOD-CHAIN PATHWAYS AND MEIs

These pathways refer not only to the human food chain but also to the ecological food chain. Terrestrial trophic relationships are numerous and complex. A few pathways have been selected as perhaps most important for assessing sludge applications. These ecological pathways involve plants, soil biota and their consumers. Pathways leading to human exposure are also given special consideration.

3.1.1. Crops for Human Consumption.

This pathway (sludge-soil-plant-human toxicity) is important wherever crops for human consumption are grown or may be grown subsequent to sludge application. Uptake of sludge contaminants is assumed to occur through the plant roots. Direct adherence of sludge or soil to crop surfaces is minimal; crops are washed before consumption.

The relevant practices for this pathway include agricultural use and use of D&M products for home gardens or in commercial enterprises where crops for human consumption are raised, whether in pots (e.g., hothouse production) or in the field (e.g., truck farming).

For agricultural use and field use of D&M products, the MEI could be defined as an individual residing in a region where a relatively high percentage of the available cropland receives sewage sludge applications. All crops in the diet could be presumed to be affected owing to crops from sludged and nonsludged lands being completely mixed within the region. The percentage of the diet potentially affected would be much higher, however, where D&M products are used for home gardening. A scenario in which the individual grows a large proportion of his or her own food would result in higher risk.

The future uses of agricultural lands may include residential development. Risk is therefore assessed on the basis of eventual suitability for home gardening.*

It is assumed that few plants grown on forest lands are ordinarily consumed by humans and that foods present where sludge has been applied will not be harvested, since required warning signs restrict access (see Section 2.2.2.). This pathway is, therefore, not considered for forest land under its current use. However, the future use of forest land may include agricultural use or residential development. Since criteria are intended to protect future use, risk is assessed on the basis of eventual suitability for agriculture or home gardening.* Similarly, reclaimed land may eventually be used for agriculture or residences.

Lands dedicated to sludge disposal do not require assessment by this pathway, however, since crops for human consumption are not grown and future property owners are notified that such crops should not be grown.

D&M products not suited for home garden use may be applied only where there is considered to be virtually no likelihood of land conversion to residential use (i.e., roadsides). All other D&M uses require an assessment by this pathway.

3.1.2. Soil Ingestion by Children. Human adults may ingest some soil, but the amounts consumed by young (i.e., preschool) children are much greater. These children constitute the MEI for this pathway (sludge-human toxicity). Since D&M sludge is not necessarily soil-incorporated, it is assumed that children may ingest sludge directly. Preschool children are assumed to be exposed in residential areas where D&M sludge has been applied to gardens, lawns, landscaped areas or turf farms providing turf for residential use. Park and recreational areas could also be sites of exposure. Sludge application to agricultural, forest and reclaimed lands is assumed not to result in exposure of preschoolers. Following land-use conversion, however, such exposures are considered to be possible. Dedicated land is not assessed according to future use because of warning statements in the deed and required hazard evaluation procedures if land is converted (see Section 2.2.4.2.).

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*If physical terrain or some other factor(s) completely preclude the possibility of any such future use, it may be desirable to conduct a site-specific risk assessment based on continued use as an agricultural or forest site.

3.1.3. Herbivorous Animals for Human Consumption. Two separate pathways are considered whereby animal products may become contaminated: 1) sludge-soil-plant-animal-human toxicity, and 2) sludge-animal (direct ingestion)-human toxicity. By the first pathway, row crops (e.g., corn) or other forage crops (e.g., grasses) are grown on sludge-amended soils and take up contaminants through the roots. The crops are harvested for animal consumption. By the second, sludge is applied over growing forage crops and adheres to crop surfaces or remains in the thatch layer on the soil surface. The crop is then harvested or grazed shortly after sludge application, resulting in direct ingestion of sludge particles. Alternatively, sludge is incorporated into the soil. The land is then grazed, and heavy grazing pressure is assumed to maximize soil ingestion. The MEI is the human consumer of these animal products.

The first of these two pathways (uptake) is clearly important when sludge is applied to agricultural lands, since animal feeds may be grown.

The importance of the second (direct ingestion) is partially dependent on whether or not surface applications without soil-incorporation are permitted. The methodology assumes soil incorporation is not required for pasture crops; the criteria calculation procedures can be used to determine whether or not this practice would be acceptable (see Section 2.2.1.2.).

When sludge is applied to forests, forage plants may be contaminated by uptake or by direct adherence. Herbivores, such as deer that are wide-ranging, may forage in sludged areas and may be taken by hunters in other areas. An individual consuming large amounts of wild game would be the MEI. Conversion of forest or reclaimed lands to agricultural use would also result in human exposure through meat consumption, as discussed above.

Reclaimed lands are to be protected according to potential future use, including forest or agricultural use, as stated earlier. Dedicated lands for sludge disposal need not be regulated for these pathways, since human food-chain crops are not produced, and conversion of use is only permitted following hazard evaluation (see Section 2.2.4.). Grazing or production of feed for animals consumed by humans is assumed not to occur where D&M sludge products are used (see Section 2.3.)

3.1.4. Toxicity to Herbivorous Animals. The exposure pathways for herbivorous animals are as described in the previous section, but the end-point of concern is toxicity to the animals themselves, which constitute the MEI. The pathways are 1) sludge-soil-plant-animal toxicity, and 2) sludge-animal toxicity (direct ingestion). For these pathways, it does not matter whether the animals are subsequently consumed by humans. The management practices to which these pathways apply are the same as described above, except that it is assumed that wildlife may forage on lawns, gardens, etc., where D&M sludge products are used.

3.1.5. Phytotoxicity. This pathway is described as sludge-soil-plant toxicity. Toxic effects in plants are of concern for most sludge application practices, since the purpose of most types of utilization is to promote plant growth. On land dedicated to sludge disposal, plant growth may be important in stabilizing the soil to curb erosion and in protecting groundwater by removing available nitrogen. However, not all dedicated-land disposal programs encourage vegetation, and therefore evaluation of this pathway is not required. This pathway should be evaluated for all other management practices, however. The MEI, or vegetation type to be protected, may be varied to match the land use if sufficient data are available to adequately assess effects for different vegetation types; otherwise, the most sensitive plant for which data are available will be assumed to represent all plants.

3.1.6. Toxicity to Soil Biota or Their Predators. Two pathways are considered here: 1) sludge-soil-soil biota toxicity, and 2) sludge-soil-soil biota-predator toxicity. The term "soil biota" is intended to be interpreted broadly. The first pathway examines effects on a broad range of organisms including microorganisms, soil invertebrates such as earthworms, or various arthropods living in or near the soil, as long as potential effects in these organisms can be related to soil concentrations. The second pathway examines effects on predators of these organisms, especially small mammals and birds. These predators could include insectivores, for example, as long as available data permit the contaminant concentrations in their prey to be related to soil concentration.

3.2. PARTICULATE RESUSPENSION PATHWAY

Particulate resuspension leading to human inhalation exposure may be of concern in certain situations. This concern probably can be limited to practices in which sludge is applied to large areas (>1 ha) where established vegetation is lacking or where mechanical resuspension, such as by tilling, may occur. These situations include agricultural use, land reclamation use and dedicated land disposal, and also outdoor nursery operations, truck farms, turf farms and highway landscaping projects using D&M sludge products. A tractor driver performing tilling operations is examined as the MEI.

3.3. SURFACE RUNOFF PATHWAY

Contaminants in sludge applied to soil may be transported in surface runoff to receiving waters including streams, lakes or estuaries. Harmful effects could, therefore, occur in aquatic organisms residing in the water or in humans and animals drinking the water or consuming aquatic organisms living in the water. The runoff pathway should be considered to pose a potential problem except where the sludge is completely contained, as in indoor nursery operations. Site size tends to be more limited for most D&M applications than for the other land application practices, and therefore, the likelihood of runoff impacts is usually minimal. However, since application to large sites is not ruled out, D&M uses are not excluded.

3.4. GROUNDWATER PATHWAY

Subsurface transport of contaminants to groundwater, and subsequent ingestion by humans, may be of concern where sludge is applied to land. Like surface runoff, this pathway is considered potentially important except where sludge is completely contained. The MEI is an individual obtaining drinking water from a nearby well.

3.5. VAPORIZATION PATHWAY

Volatile contaminants may vaporize from land-applied sludge, and subsequently may be transported downwind to cause human exposure. Vaporization is not a potential problem where composted, heat-dried or air-dried sludge is used; in these cases volatile contaminants are considered to have had adequate time to escape. Therefore, D&M uses are not evaluated for this pathway, but agricultural, forest and land-reclamation uses and dedicated-land disposal require evaluation.

4. CRITERIA CALCULATION METHODS FOR TERRESTRIAL FOOD-CHAIN EXPOSURE PATHWAYS

4.1. TERRESTRIAL FOOD CHAIN -- GENERAL CONSIDERATIONS

Several factors affect many of the exposure pathways associated with the terrestrial food chain. These factors are addressed below and will then be referred to in later chapters dealing with specific pathways. The assumptions involved are presented in Table 4-1 and also are discussed in the text.

4.1.1. Calculation of Application Rates To Achieve Specified Soil Concentrations.

The criteria calculation procedures given in the following pages frequently calculate a reference soil concentration, RLC (in µg/g DW), that will protect human health or the environment. It is then necessary to translate the RLC into a corresponding reference application rate of the pollutant, RP (in kg/ha). Calculation of the RP must reflect soil incorporation practices and also loss rate of the contaminant from the soil.

4.1.1.1. SOIL INCORPORATION OF SLUDGE -- In many, but not all, land application practices, sludge is incorporated into the upper layer of soil before crops or other vegetation are grown. Incorporation is usually accomplished by disking or chisel plowing of surface-applied sludge or by direct injection into the soil. An assumption typically used is that sludge is mixed into the soil to a depth of 15 cm (6 in), and that the soil has a bulk density of 1.33 g/cm^3; therefore, the dry mass of this upper layer of soil is 2x10^3 t/ha (Naylor and Loehr, 1982; Donahue et al., 1983). This assumption results in the following relationship between contaminant application rate and initial contaminant concentration in soil:

$$RP = RLC \times MS \times 10^{-3} \qquad (4\text{-}1)$$

where:

RP = reference application rate of pollutant (kg/ha)
RLC = reference soil concentration of pollutant (µg/g DW)
MS = 2x10^3 t/ha = assumed mass of soil in upper 15 cm
10^{-3} = conversion factor (kg/g)

TABLE 4-1

Assumptions for Terrestrial Food Chain

Functional Area	Assumption	Ramifications/Limitations
Soil incorporation of sludge (Section 4.1.1.1.)	If soil incorporation is assumed, incorporation depth is 15 cm, and the soil has a bulk density of 1.33 g/cm³.	By this assumption, a soil concentration of 1 μg/g corresponds to a pollutant application rate of 2 kg/ha. If actual depth (and mass) is less, impacts on soil biota in the incorporation layer could be underpredicted (and vice versa). Ramifications for effects on plants are less clear, since less of the root zone is contaminated as incorporation depth decreases.
	Soil background concentration is ordinarily considered zero for synthetic organic compounds.	Effects could be underpredicted if background concentration is not zero. Where site-specific data indicate nonzero background concentrations, actual concentrations should be used for those localities.
Contaminant loss from soils (Section 4.1.1.2.)	Category 1 contaminants are assumed to be conserved indefinitely in the upper layer of the soil. These include most metals (e.g., Cd, Pb, Cu, Zn, Ni) that are not subject to significant loss by volatilization or leaching.	Although most heavy metals are tightly bound to soils, measurements tend to show that this assumption often overpredicts concentrations following sludge application. This discrepancy probably indicates some loss; therefore, this assumption probably overpredicts certain hazards.
	Category 2 contaminants are those subject to loss. They include organic compounds that are degraded and the heavy metals (e.g., Hg, Se, B, As) that may be lost from the soil by volatilization or leaching. Degradation of organics contaminants is first order.	Could over- or underpredict degradation rate, which is complex and not necessarily first order.
Plant uptake of inorganics (Section 4.1.2.1.)	Plant uptake response is curvilinear when expressed as function of cumulative contaminant application, and approaches a horizontal asymptote ("plateau").	Implies that once plateau is reached, further sludge additions will not increase plant tissue concentration.
	Height (i.e., tissue concentration) of plateau is a function of contaminant concentration in sludge and other sludge characteristics.	Implies that it may be possible to express maximum plant tissue concentration as a function of sludge concentration instead of application rate. However, other variables could confound this relationship.
	Uptake response slope and plateau are higher in the first year of sludge application than in later years, and following repeated annual applications.	Risk calculations based on first-year data may overpredict long-term risk. Calculations based on multiyear data may underpredict initial contamination levels. However, other variables could confound this distinction.
	Uptake response slope and plateau for most metals are higher in soils of pH<6.0 than those ≥6.0.	Risk in these situations should be modeled separately; however, other variables could confound this distinction.

TABLE 4-1 (cont.)

Functional Area	Assumption	Ramifications/Limitations
Plant uptake of inorganics (Section 4.1.2.1.) (cont.)	Relative uptake response among different crops is fairly consistent across soils and sludges.	A careful evaluation of the variability of relative uptake is needed. Preliminary indications from the draft Las Vegas workshop report are that relative uptake may vary by a factor of 2-5.
	Plant uptake is treated as linear with application rate until highly toxic concentrations in tissue are reached (this assumption used if plateau cannot be demonstrated).	May overpredict tissue response to contaminant application if relationship is truly curvilinear.
Plant uptake of organics (Section 4.1.2.2.)	Plant uptake is treated as linear with soil concentration until highly toxic concentrations in tissue are reached.	May overpredict tissue response to contaminant application if relationship is truly curvilinear.
Animal uptake of contaminants (Section 4.1.2.3.)	Animal tissue concentration is treated as a linear function of feed concentration.	Could under- or overpredict tissue concentration outside the observed range of response.
	Pure chemicals added to diet can be used to determine uptake response slope.	Availability of chemicals in sludge or sludge-derived products may differ; especially, it may be lower, so that uptake is overpredicted.
Toxicity thresholds for nonhuman organisms (Section 4.1.3.)	All long-term inhibitory effects should be considered adverse.	Some "inhibitory" changes might not significantly affect the individual survival or population dynamics. Conversely, some ecologically important effects might not be observed in toxicity tests.
	The geometric mean of exposure levels bracketing the appearance of an adverse effect should be used as the threshold.	The true threshold may lie at any point between these two levels and may be over- or underpredicted by this method.
	The form of a contaminant used in a study should not be considered equally bioavailable and toxic as the form in sludge or sludge-derived products, unless suitable data using sludge are not available.	Availability of chemicals in sludge or sludge-derived products may differ; particularly, it may be lower, so that toxicity is overpredicted.
Human diet (Section 4.1.4.)	The FDA Revised Total Diet Study food list (Pennington, 1983) is representative of the U.S. diet. The age/sex group with the highest consumption of a given contaminant (typically the 25- to 30-year-old male) is the MEI in that instance.	While very complete and detailed, the Pennington diet provides no information on variability within age/sex groups. For example, vegetable consumption by lacto-ovo-vegetarians is not well represented.

From this equation, a soil concentration of 1 µg/g DW corresponds to a pollutant application rate of 2 kg/ha.*

Equation 4-1 is simplified in that is does not take into account background concentrations of the pollutant that may already be present, whether natural or from other pollution sources. If it is assumed the total mass of the soil-sludge mixture is equal to MS, then the amount of soil is MS-AR, where AR is the sludge application rate (in t DW/ha). The reference application rate, RP, must be reduced by an amount corresponding to the contaminant mass contributed by the soil:

$$RP = [(RLC \times MS) - BS(MS-AR)] \times 10^{-3} \qquad (4\text{-}2)$$

where BS = background concentration of pollutant in soil (µg/g DW). If AR is very small compared with MS, as is often the case, AR may be dropped from Equation 4-3. The equation then reduces to the following:

$$RP = (RLC-BS) \times MS \times 10^{-3} \qquad (4\text{-}3)$$

where:

RP = reference application rate of pollutant (kg/ha)
RLC = reference soil concentration of pollutant (µg/g DW)
BS = background concentration of pollutant in soil (µg/g DW)
MS = 2×10^3 t/ha = assumed mass of soil in upper 15 cm
10^{-3} = conversion factor (kg/g)

For organic pollutants the background concentration in soil (BS) ordinarily is assumed to be zero, so that criteria for sludge application are calculated independently of other contamination episodes. Equations 4-2 and 4-3 thus ordinarily reduce to Equation 4-1 for organics. However, Equation 4-2 or 4-3 may still be appropriate for organics on a site-specific basis, if warranted by existing contamination.

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*If soil incorporation depth were greater, i.e., 20 cm, an area/mass of 2.6×10^3 t/ha would be calculated. In this case, if RLC = 1 µg/g DW, then RP = 2.6 kg/ha.

If the contaminant persists indefinitely in the upper soil layer once applied, then RP in the above equations represents a cumulative pollutant application rate, which will be denoted as RP_c. If the pollutant is lost over time, then the calculated RP gives the amount that could be applied in a single sludge application, where no waiting or conversion period is assumed. This rate will be denoted as RP_s. To calculate a permissible single-application rate that is to be followed by a waiting period or land-use conversion period (RP_{sT}) or to calculate an annual application rate (RP_a), the loss rate from soils must also be considered.

4.1.1.2. CONTAMINANT LOSS FROM SOILS -- Contaminants may be lost from soils as a result of numerous processes, including leaching, volatilization, and chemical and biological degradation. These processes may be occurring simultaneously and at different rates.

Many of the inorganic contaminants of concern are not subject to volatilization or degradation, and leaching is minimal because they are tightly bound to soil. Particulates may be lost to runoff, but if sludge is soil-incorporated, loss of some soil and sludge particles will not affect contaminant concentration in the remaining soil. Therefore, this methodology usually assumes that inorganic contaminants are conserved indefinitely in the upper layer. [Inorganics may be treated in the same manner as organics, however, if a loss rate constant can be estimated.]

Organic contaminants, on the other hand, may be subject to all of these loss processes that are extremely difficult to model in order to predict the rate of loss. A simpler means to estimate loss is based on empirical data from soil systems where soil concentrations have been followed over time. These data may be used to estimate a first-order loss rate constant for the pollutant. The use of such a rate constant is recognized to be an over-simplification, since the processes involved are complex and not necessarily first order. Rate constants should be derived from field data wherever possible, or may be estimated by analogy to other closely related chemicals. Where no basis for an estimate is available, no loss should be assumed.

First-order loss is represented by the following equation:

$$C_t = C_o\ e^{-kt} \tag{4-4}$$

where:

C_t = concentration at time t (µg/g)
C_o = concentration at time zero (µg/g)
e = base of natural logarithms, 2.718 (unitless)
k = loss rate constant ($years^{-1}$)
t = time (years)

If BS is assumed to be zero, the following is true:

$$RP_s = RP_{sT} \times e^{-kT} \tag{4-5}$$

where:

RP_s = reference single-application rate, with no waiting period (kg/ha)

RP_{sT} = reference single-application rate followed by waiting period (kg/ha)

k = rate constant for contaminant loss from soil ($years^{-1}$)

T = waiting (or land-use conversion) period (years)

e = base of natural logarithms, 2.718 (unitless)

Thus, from Equations 4-1 and 4-5, an expression can be derived for calculating the permissible application rate of a pollutant subject to loss over time when a one-time application will be followed by a waiting period:

$$RP_{sT} = RLC \times MS \times 10^{-3} \times e^{kT} \tag{4-6}$$

where:

RP_{sT} = reference single-application rate followed by waiting period (kg/ha)

RLC = reference soil concentration of pollutant (μg/g DW)

MS = 2x10^{3} t/ha = assumed mass of soil in upper 15 cm

k = rate constant for contaminant loss from soil (years^{-1})

T = waiting (or land-use conversion) period (years)

e = base of natural logarithms, 2.718 (unitless)

Ordinarily, however, it is desired to determine an amount that can be applied annually, RP_a (in kg/ha). To do so, it is first necessary to solve Equation 4-2 for the reference soil concentration, RLC:

$$RLC = \frac{RP \times 10^3 + BS\ (MS-AR)}{MS} \tag{4-7}$$

where:

RLC = reference soil concentration of pollutant (μg/g DW)
RP = reference application rate of pollutant (kg/ha)
10^{3} = conversion factor (g/kg)
BS = background concentration of pollutant in soil (μg/g DW)
MS = 2x10^{3} t/ha = assumed mass of soil in upper 15 cm
AR = sludge application rate (t DW/ha)

When the first annual application, RP_a, is applied, the background BS is assumed to be zero. Therefore, the initial soil concentration (LC_o) is as follows:

$$LC_o = \frac{RP_a \times 10^3}{MS} \tag{4-8}$$

After 1 year's time, but before a second application, the soil concentration ($LC_{1'}$) is as follows:

$$LC_{1'} = LC_o\ e^{-k} = \left(\frac{RP_a \times 10^3}{MS}\right) e^{-k} \tag{4-9}$$

When the second application is made at year 1, the soil concentration (LC_1) is determined from Equation 4-7, using the residual concentration from the first application, $LC_{1'}$, as the value of BS:

$$LC_1 = \frac{RP_a \times 10^3 + LC_{1'}\ (MS-AR_a)}{MS}$$

$$= \frac{RP_a \times 10^3 + [(RP_a \times 10^3)/MS]e^{-k}(MS-AR_a)}{MS}$$

$$= \frac{RP_a \times 10^3}{MS}\left[1 + \left(\frac{MS-AR_a}{MS}\right)e^{-k}\right] \quad (4\text{-}10)$$

Similarly, when applications are repeated annually for n years, the concentration immediately following the nth application (LC_n) is as follows:

$$LC_n = \frac{RP_a \times 10^3}{MS}[1 + De^{-k} + D^2e^{-2k} + \ldots + D^{n-1}e^{(1-n)k}] \quad (4\text{-}11)$$

where:

$D = (MS-AR_a)/MS$

When the reference soil concentration, RLC, from the criteria calculation procedures given later is used for LC_n, then RP_a is the corresponding reference application rate that can be applied annually. Solving for RP_a,

$$RP_a = RLC \times MS \times 10^{-3}\,[1 + De^{-k} + D^2e^{-2k} + \ldots + D^{n-1}e^{(1-n)k}]^{-1} \quad (4\text{-}12)$$

This equation can be further generalized to include the case where a waiting or conversion period, T, follows the nth application:

$$RP_a = RLC \times MS \times 10^{-3}\,e^{kT}\,[1 + De^{-k} + D^2e^{-2k} + \ldots + D^{n-1}e^{(1-n)k}] \quad (4\text{-}13)$$

where:

RP_a = reference annual application rate of pollutant (kg/ha)
RLC = reference soil concentration of pollutant (μg/g DW)
MS = 2×10^3 t/ha = assumed mass of soil in upper 15 cm
10^{-3} = conversion factor (kg/g)
e = base of natural logarithms, 2.718 (unitless)
k = loss rate constant (years^{-1})
T = waiting (or land-use conversion) period (years)
D = $(MS-AR_a)/MS$
AR_a = annual application rate (t DW/ha)

Thus, annual application rates for dissipating compounds may be calculated as a function of the limiting soil concentration, pollutant loss rate constant, waiting period since last application and sludge application rate.

As noted previously, in most cases AR_a is very small compared with MS, and D reduces to 1 and may be dropped from Equation 4-13.

4.1.1.3. INPUT PARAMETER REQUIREMENTS FOR CALCULATING APPLICATION RATES -- Several input parameters may be required for calculating pollutant application rates from the reference soil concentration. The soil mass, MS, and loss rate constant, k, have been discussed previously. The other parameters are discussed in the following text.

4.1.1.3.1. Waiting Period or Land-Use Conversion Period (T) -- As mentioned in Section 2.2.1.2., waiting periods following sludge application may be evaluated as a useful means of reducing risk from certain activities, such as grazing of cattle or planting of crops. Suggested values for T in these instances will be given as part of the discussion of those specific exposure pathways rather than here. As also mentioned in Chapters 2 and 3 (see Table 3-1), certain exposure pathways may not be relevant until land-use conversion occurs. It may be assumed that some period of time, T, is required for such conversion to occur. This report will not attempt to specify the time periods that could be associated with various types of conversion, however.

4.1.1.3.2. Number of Annual Sludge Applications (n) -- Since there is no established limit to the number of sludge applications that may occur in most utilization practices, an infinite number should ordinarily be assumed. In practical terms, if $n = 5.6/k$ then the final term, $e^{(1-n)/k}$, in Equation 4-13 will be <0.01, and the result of further increasing n will be negligible. This approach will be used here. In certain utilization practices, however, especially where site-specific information can be used, it may be appropriate to assume a more finite value of n. For example, land reclamation may involve only 1 or a few years of sludge application.

4.1.1.3.3. Sludge Application Rate (AR) -- A cumulative rate, AR_c (in t DW/ha), is used in Equation 4-2, and an annual rate, AR_a (in t DW/ha), is used in Equations 4-12 and 4-13. Since large values of AR slightly increase RP, low values should ordinarily be assumed for a protective approach. AR_a typically is ~5 t DW/ha for many agricultural uses. AR_c can be much higher, since it is assumed that sludge applications may be repeated indefinitely, but if only a single application is made, $AR_c = AR_a$. Therefore, AR should ordinarily be considered zero for purposes of criteria calculation.

4.1.1.3.4. Background Soil Concentration of Pollutant (BS) -- As stated previously, BS (in µg/g DW) may be the natural background concentration or may result from other pollution sources. In national criteria derivation, it is suggested that mean values, such as those arising from natural background or very widespread pollution (such as lead), be used. Locally elevated concentrations, either from unusual natural background levels or localized pollution sources, should be dealt with on a site-specific basis. Values of BS should be derived from national or regional surveys of soil concentration. For metals, pollutant additions in sludge are considered on the basis of total metal, rather than extractable metal. Therefore, soil analyses should also be of total metal. Extractable metal is that which can be extracted by dilute acid (such as 1 N HNO_3) or a chelating agent (such as EDTA), whereas total metal is approximated following a complete digestion of the sample with concentrated acid (such as nitric-perchloric acid digestion).

4.1.2. Contaminant Uptake Relationships.

4.1.2.1. PLANT UPTAKE OF CATEGORY 1 CONTAMINANTS -- Rates of uptake of inorganic chemicals, especially metals, by plants grown in sludge-amended soils have been intensively studied. Recent reviews of plant-metal uptake relationships include those by CAST (1980), Ryan et al. (1982), Logan and Chaney (1983) and U.S. EPA (1987a). In an effort to relate the response of total dietary cadmium (Cd) to sludge-applied Cd for the purpose of assessing risk, Ryan et al. (1982) used linear regression (of plant tissue Cd concentration against applied Cd) to derive uptake response slopes for various crops.* The slope of the crop response curve to added soil Cd was different for annual and cumulative Cd additions. The annual response curve represented the more responsive situation; therefore, they felt it was judicious to use this curve and thus err on the conservative side (i.e., overestimate human exposure). Presently from our understanding of long-term metal availability from land application of sewage sludge (U.S. EPA, 1987a), it is known that the first-year response curve [annual response curve from Ryan et al. (1982)] generated by a large, single sludge addition will overestimate long-term metal accumulation in vegetative tissue and that response curves generated 4 or more years following sludge application are more appropriate models. At any rate, the underlying assumption is that for each incremental increase in soil metal there is a constant linear increase in plant tissue concentration. By this approach a cumulative metal application limit can be reached above which no further additions of sludge containing metal would be allowed.

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*In this document, the term "uptake response" (or simply "response") is used to denote an increase in tissue concentration in response to exposure to a chemical. That is, uptake response refers to the difference in pre- and postexposure concentrations. It is not used here to denote the total chemical mass taken up, as determined by concentration times yield, which is usually referred to as "uptake."

More recently, however, others have argued that Cd response is curvilinear and approaches a plateau, the level of which is not dependent on cumulative application rate but rather on the metal activity in the soil/sludge solution. This argument, as summarized by Logan and Chaney (1983) and U.S. EPA (1987a), is based on the premise that as the total amount of sludge added to soil increases, Cd availability becomes controlled by the adsorptive characteristics of the sludge rather than of the soil. Since with increasing sludge addition the soil Cd increases, crop response increases with application rate at low application rates where the soil's adsorptive capacity controls metal activity. However, if the metal adsorptive capacity of the sludge is high compared with the soil (usually assocated with high sludge rates), the soil adsorption sites that can be filled at the activity supported by the sludge will result in only a small decrease in solution activity, and the sludge adsorption properties will control solution activity and thus plant uptake. At some point, where the sludge adsorption capacity is controlling metal solution activity, plant concentration will reach a maximum (plateau) and further addition of sludge will not change plant tissue concentration. The sludge properties that are thought to control its adsorption capacity include Cd concentration, Fe concentration, Al concentration, P concentration and pH (U.S. EPA, 1987a). A thorough critical review and acceptance of this hypothesis by the scientific community and development of the data base will be necessary before it can become a basis for regulatory criteria. However, in an attempt to reflect the current state of knowledge, the present methodology will tentatively accept this hypothesis.

A comparison of the response curves generated by the linear and curvilinear models are illustrated in Figure 4-1. In the case of the

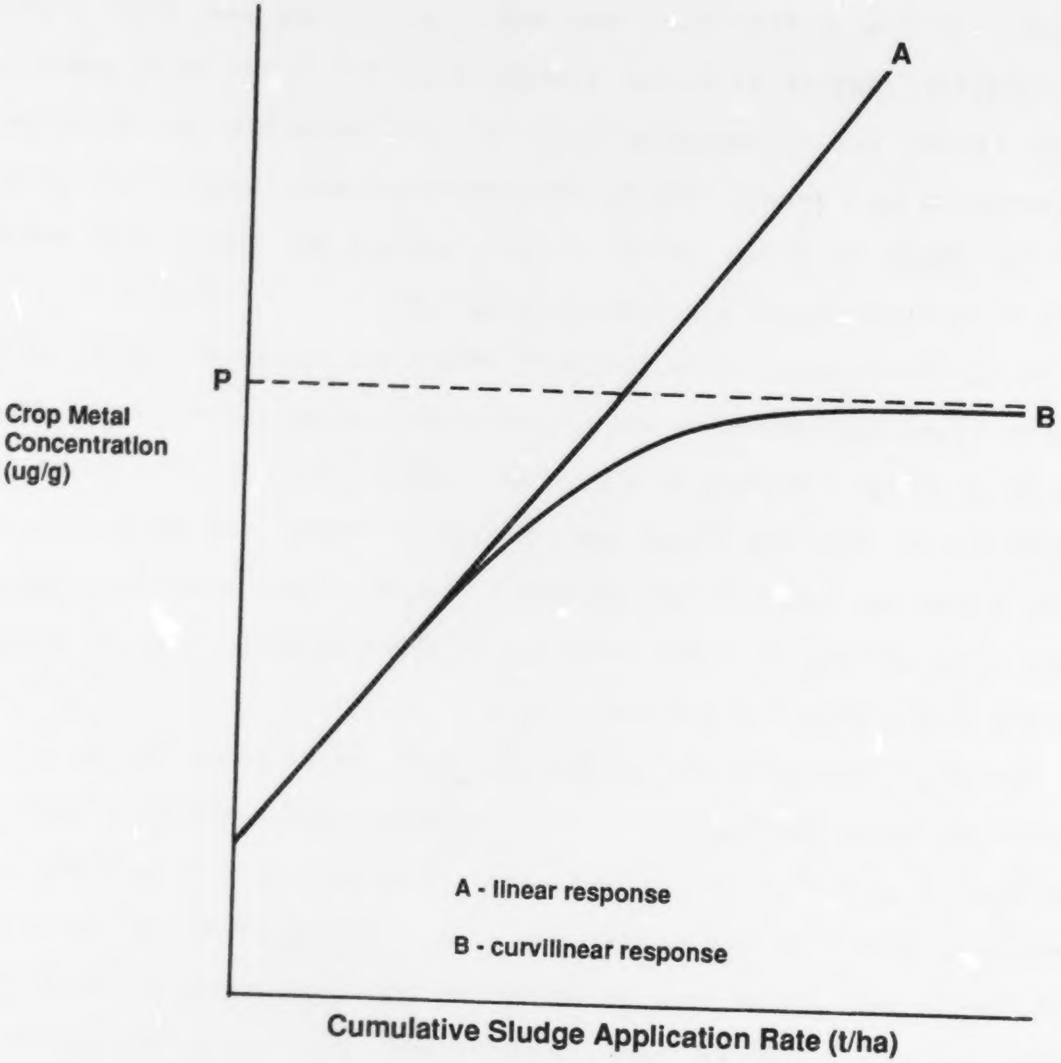

FIGURE 4-1

Curvilinear Uptake of Sludge-borne Metal by Crops curvilinear model the plant tissue concentration reaches a maximum value P (plateau), whereas the linear model assumes that no maximum value is reached. At low loading rates both models predict the same plant tissue concentration, whereas at higher loading rates the linear model predicts higher plant tissue concentration. If the acceptable plant tissue concentration were greater than P, the curvilinear model would allow for an infinite amount of sludge to be applied, whereas the linear model would allow for a finite amount of sludge to be applied.

An additional complicating factor is that crop response during the first year of sludge application is higher than that observed several years after the first sludge application (U.S. EPA, 1987a). This is illustrated in Figure 4-2 for both the linear and curvilinear model. The implication of this is that for long-term consideration, response curves generated several years after an initial sludge addition, or after multiple years of sludge addition, would be more applicable.

Both the linear model and the plateau model can be useful for assessing effects of sludge applications. Linear response slopes are easily derived and usually available for various crops, thereby providing a means for comparing relative responsiveness among crops. Plateau data, on the other hand, may be most appropriate for estimating long-term impacts of cumulative sludge addition. However, where insufficient data exist to determine plateau levels in sensitive crops, linear response slopes provide a highly conservative means of assessing risks from crop uptake of metals. Guidance for determining linear response slopes and plateaus is given below. Specific use of these values to derive criteria for various exposure pathways is discussed in later chapters.

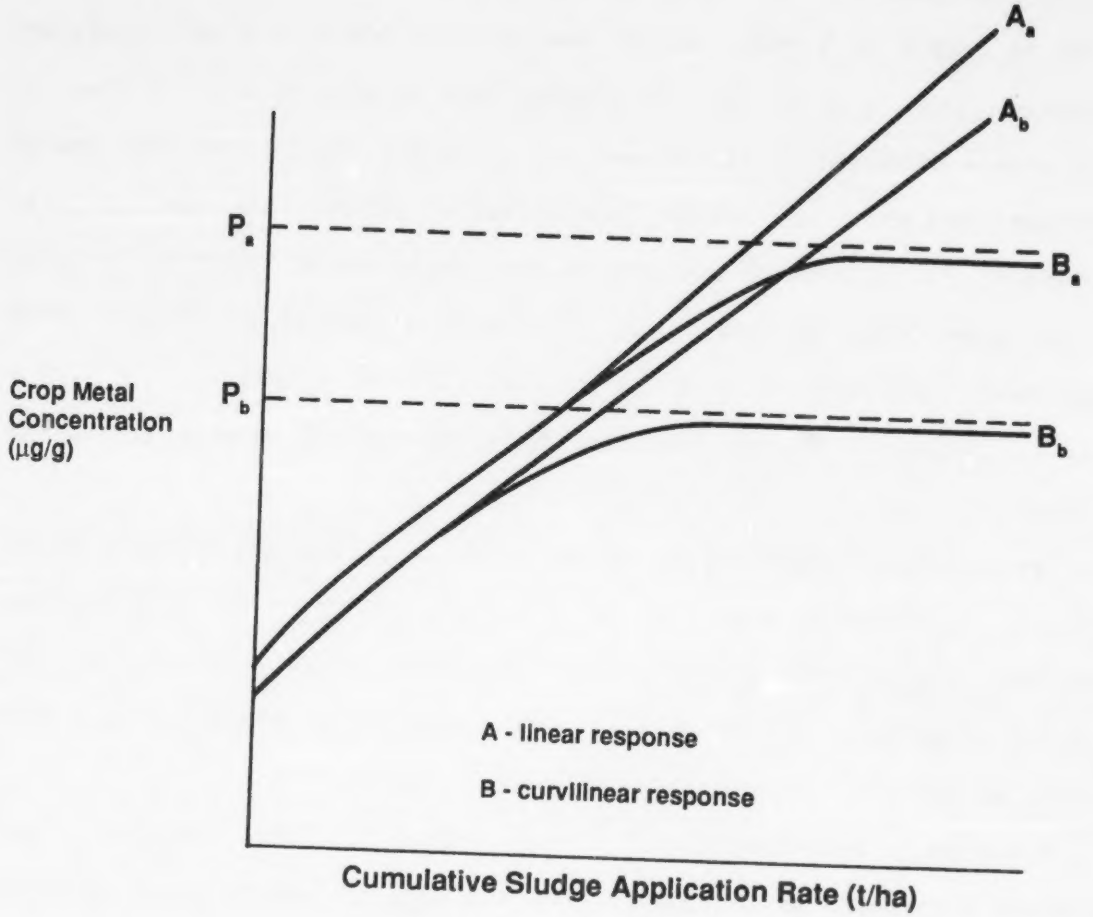

FIGURE 4-2

First-Year Vs. Multi-Year Observations

a = Crops grown in the first year of sludge application

b = Crops grown 1 or more years following sludge application, or where applications have been repeated annually

The report (U.S. EPA, 1987a) also advances the hypothesis that relative response among crops is fairly consistent across soils and sludges, at least for similar soil pH. In other words, if the linear response slope of a metal in crop A is 5 times higher than that in crop B in a well-conducted experiment using a given soil and sludge, then it will also be 5 times as high when a different sludge or soil (of a similar pH) is used, even though absolute response may differ substantially between the two studies. Therefore, the response of any crop theoretically can be expressed in terms of any other crop, as long as the two have been studied in the same valid experiment. The response of all crops could thus be expressed in terms of a single, frequently studied (and relatively responsive) index crop such as lettuce.

The hypotheses regarding the uptake response plateau and relative uptake response relationships remain to be rigorously validated for each chemical that may require criteria derivation. Therefore, criteria calculations for specific chemicals should include discussions of pertinent uptake data verifying that these hypotheses hold in each case.

4.1.2.1.1. Determination of Linear Uptake Response Slopes -- Linear response slopes can be calculated from any data set where tissue analyses and cumulative metal application rates have been recorded. Tissue analyses from various application rates in a single year (whether or not previous sludge additions have been made) are generally more easily interpreted because year-to-year variability of conditions is eliminated. Data from the first year of sludge application will generally result in higher slopes than those from later years, as mentioned above. Multi-year slopes may be more representative of typical sludge application practices.

Data derived from sludge applications in the field are most appropriate for use in risk assessments. Greenhouse studies where plants are grown in pots are known to often overpredict uptake under field conditions (Logan and Chaney, 1983). However, in the absence of field data, data from pot studies may be useful, especially where large pots are used to minimize restriction of root growth. Studies using metal salts, added either to soil or a sludge-soil mixture, also tend to overpredict field response. Therefore, metallic salt uptake data should not be used for risk assessment if sludge data are available.

Studies where plants are grown in solution culture also should not be used, as there is no reliable way to relate concentration in solution to total soil concentration in the field or application rate. Studies where sludge has been applied over growing plants demonstrate physical adherence rather than physiological uptake and therefore should not be used. Their use in assessing effects from contaminated animal forage is discussed later (see Sections 4.4. and 4.5.).

Uptake response slopes are calculated by regressing plant tissue contaminant concentration (in μg/g DW) against cumulative contaminant application rate (in kg/ha) for the various treatment levels, including the control. Note that where the control application rate is zero, the tissue concentration is greater than zero because of background occurrence of these elements. Where data from a pot study are used, soil concentrations must first be converted to application rates using the relationship discussed previously (see Section 4.1.1.1.).

Some additional considerations may be important when linear response slopes are calculated. If a data set shows a curvilinear tendency, linear regression may underestimate the slope at low application rates (and overestimate the slope at high rates). Since many studies use very high application rates to demonstrate an effect, and rates of concern may be in the lower part of the curve, it may be appropriate to recalculate the slope after dropping some of the higher points.

Conversely, a linear slope is sometimes used to estimate tissue concentrations at application rates well beyond the range of the available data. If the contaminant is phytotoxic, this extrapolation could result in predicting very high tissue concentrations that in actuality would have resulted in death of the plant (and therefore cause zero risk to higher trophic levels). A straightforward means of addressing this problem is to determine a maximum tissue concentration for a given crop, based on available phytotoxicity data, and to assume this value as an upper limit to uptake. The plant tissue concentration limit (TL) is not that which occurs at a phytotoxic threshold (that is, the level at or above which symptoms of phytotoxicity, such as a modest yield reduction or foliar discoloration, first appear), since threshold effects do not necessarily preclude contaminant passage up the food chain. Rather, maximum concentrations are those associated with severe yield reduction (>75%) or death of the plant. When a maximum tissue concentration (TL) is imposed as a ceiling, the resulting assumed uptake relationship is as shown in Figure 4-3. Plant tissue concentration at which phytotoxicity occurs is dependent upon a number of soil and sludge factors and can be expected to vary over a wide range. Therefore, the value used in criteria calculations for specific chemicals should include a discussion of pertinent data.

4.1.2.1.2. Determination of the Uptake Response Plateau -- If uptake response is assessed on the basis of a plateau, the tissue concentration at which a plateau occurs must be estimated for a given study. The shape or

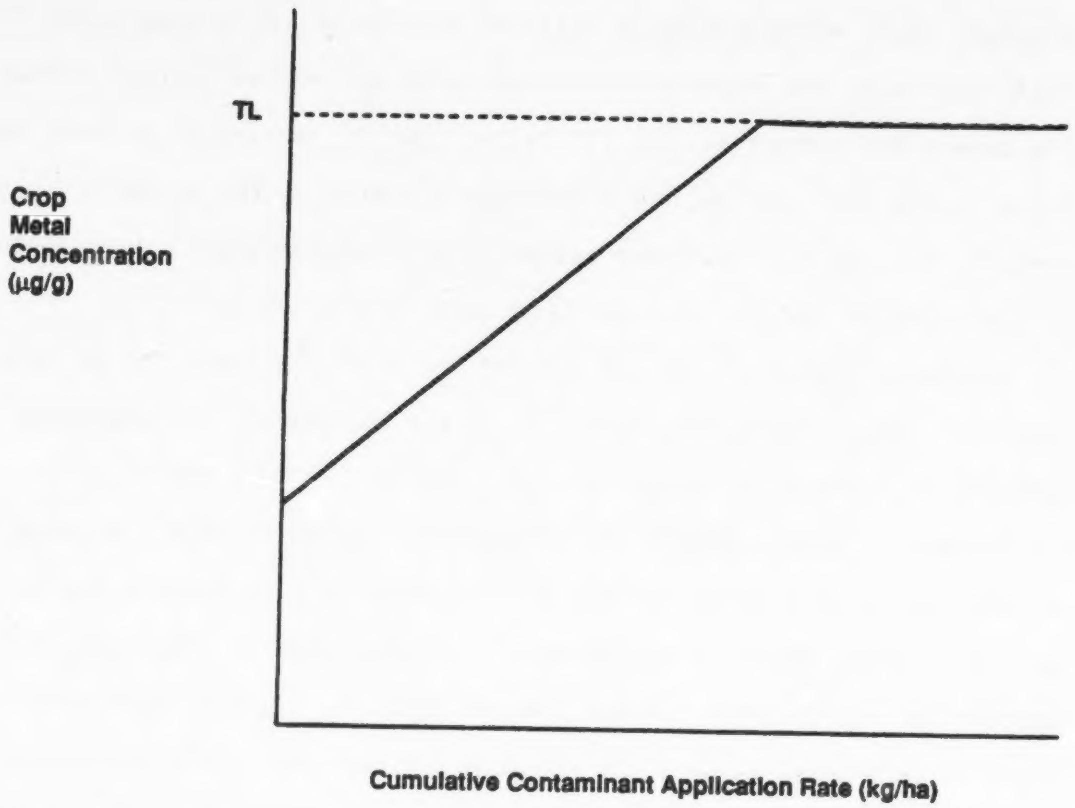

FIGURE 4-3

Limitation by Phytotoxicity of Linear Uptake Response*

*For explanation, see text.

slope of the lower portion of the curve is not important. Nonlinear regression techniques for fitting a curve to the data and determining and placing confidence limits around the asymptote should be used. If an upper confidence limit of the asymptote is used as the plateau, the number of points and goodness-of-fit of the data will help determine how low a plateau can be assumed. This would provide a built-in measure of safety when using less-than-ideal data and would be consistent with procedures currently used in the Agency for estimating cancer potency, that is, the use of an upper bound value rather than the maximum-likelihood estimate of the parameter sought. However, the maximum-likelihood estimate would also be useful, especially in illustrating the variability associated with this parameter.

Nonlinear regression may be carried out with the same type of data as used for linear regression, that is, tissue contaminant concentrations (in µg/g DW) vs. cumulative contaminant applications (in kg/ha DW).

4.1.2.2. PLANT UPTAKE OF ORGANICS -- Linear uptake response is assumed for organic chemicals and is calculated as described for inorganics, but with some important differences. Because organic compounds tend to degrade in soil, plant tissue concentration is usually expressed as a function of a measured soil concentration, rather than application rate, in most available studies. Therefore, the soil concentration (in µg/g dry weight) is used as the x axis to determine the slope.

In addition, because soil concentration rather than application rate is used, and because most of the compounds of concern are xenobiotics, tissue concentration can be assumed to be zero when soil concentration is zero. Therefore, the slope reduces to a bioconcentration factor (BCF) that can be derived from a single data pair, as is commonly done to derive BCFs for aquatic organisms. Few studies have quantified uptake of organic compounds from land-applied sludge. Estimations of response slope may need to rely on other data, such as from soil-applied pesticide studies where plant uptake through roots occurred.

4.1.2.3. **CONTAMINANT UPTAKE BY ANIMAL TISSUES** -- Linear response slopes are derived for uptake of inorganics or organics by animal tissues consumed by humans. Tissue concentration is regressed against concentration in feed. Tissue concentrations in the literature may be expressed in dry or wet weight, but dry weight is preferred. For uniformity in applying this methodology, all slopes should be derived based on dry-weight (moisture-free, but including fat) concentrations in tissue and feed. Conversion from wet to dry weight for various tissues should be made according to percent-moisture values given in USDA (1975).

For lipophilic organics, tissue concentration is often expressed on a fat basis (μg/g fat). If so, the slope should also be expressed on a fat basis rather than converted to dry-weight basis. Also, the slope for organics may be the same as a BCF derived from a single data point (that is, animal tissue concentration ÷ feed concentration), as described previously for plant uptake of organics (Section 4.1.2.2.).

The best studies for deriving uptake information are those in which sludge or sludge-grown crops are used as part or all of the diet for animals (such as cattle, sheep, swine and poultry) typically consumed by humans. Studies in which the diet has been amended with pure chemicals should be used only in the absence of these data, since the added forms often are more bioavailable. Tissues analyzed may include muscle, kidney, liver and various other organs less frequently consumed by humans.

4.1.3. **Toxicity Thresholds for Nonhuman Organisms.** Detailed methods have been developed by the U.S. EPA for determining toxicant exposure levels that should not be exceeded in humans (Federal Register, 1980). When sludge is applied to land, other organisms, such as soil biota and their predators, plants and grazing animals should be protected as well as humans. However, specific methods for selecting threshold levels for protecting these diverse groups have not been articulated. It may be difficult to determine what studies are most appropriate, what effects are of concern, and how to select protective values based on the available information.

The U.S. EPA Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (U.S. EPA, 1984c) comprehensively address these issues with regard to aquatic organisms. These Guidelines list acceptable types of toxicity tests and establish a minimum data base for the number of species required to have been tested. The threshold, or "chronic value," is defined as the geometric mean of the lowest exposure level causing, and the highest level not causing, a statistically significant, adverse effect in a given species. The final value is then calculated as the level that protects 95% of the tested genera of aquatic species. If a commercially or recreationally important species requires greater protection, the final value is lowered accordingly.

It would be desirable to use similar procedures for protecting terrestrial organisms; however, sufficient information may not be available for a comparably systematic approach. The following general guidelines are suggested for determining toxicity thresholds in plants, invertebrates and vertebrates:

1. Long-term inhibitory effects should be considered adverse unless evidence to the contrary is available. These effects usually include reductions in growth, fecundity, lifespan or performance, as well as symptomatic manifestations of toxicity. However, temporary reductions in soil microbial activity or diversity should not be considered adverse unless there are demonstrated long-term effects on ecosystem parameters. Where effects cannot be attributed to one chemical, such as studies where exposure is to sludge, thresholds ordinarily cannot be determined.

2. The geometric mean of exposure levels bracketing an adverse effect should be used as the threshold. For example, if exposure levels are 1, 10 and 100, and effects are significant at 100, a value of ~30 ($\sim[10\times100]^{1/2}$) should be used. Where effects occur at the lowest exposure level, and other studies better defining the threshold value are unavailable, no threshold value can be determined. Where results were not statistically tested, careful judgment should be used to determine the meaningfulness of a given change.

3. The form of a contaminant used in a study should not be considered equivalent in bioavailability to the form present in sludge or migrating from sludge unless no better data are available. Studies with sludge or sludge-grown crops usually cannot be used to establish a toxicity threshold because of the presence of other pollutants. Therefore, it may be necessary to rely on results of studies using pure forms of the contaminant. If, however, a study using sludge, sludge-grown crops or some other appropriate vector demonstrates lower bioavailability in a realistic exposure situation, such information should be taken into account when establishing the threshold. However, a study showing little response to a sludge-borne chemical in species A cannot be taken to indicate that a more sensitive response to the pure form in species B should be disregarded.

4. Where studies with few species are available for a given chemical, the results with the most sensitive species should be used to determine the threshold. Where eight or more diverse species have been studied, procedures for estimating the fifth percentile of response may be used, as described in the Aquatic Life Guidelines (U.S. EPA, 1984c), as long as commercially important species are protected.

5. Where several tests have been conducted for a given species, results appearing to be outliers should be disregarded.

These general guidelines should be applied together with careful scientific judgment to derive toxicity threshold values for various types of organisms.

4.1.4. Human Diet. Humans may be exposed to sludge-borne contaminants in crops or animal products that have taken up the contaminants by the soil or diet, respectively. To quantify potential dietary exposures, it is necessary to estimate the amounts of various types of foods in the human diet. The most up-to-date and detailed source of information regarding food consumption habits of the U.S. population is the FDA Revised Total Diet Study food list (Pennington, 1983). This list is based on combined results of the USDA Nationwide Food Consumption Survey (1977-1978) and the Second National Health and Nutrition Examination Survey (1976-1980). The list provides average, fresh-weight consumption data for over 200 foods (201 adult foods; 33 infant/junior foods) for eight age/sex groups ranging from infancy to 60-65 years of age.

While the Pennington (1983) food list provides a very detailed picture of the human diet, it cannot be used in its published form for risk assessments of the present type. Many of the food items listed are complex prepared foods (such as soup, pizza), rather then the raw commodities (such as crops, meats) for which contaminant uptake data are available. Therefore, to predict the impact of sludge application using uptake data, it is necessary to reorganize the diet to determine the respective consumed amounts of these raw commodities.

Two previous efforts have been made to reorganize the Pennington (1983) diet. In 1981, the U.S. EPA Office of Solid Waste proposed an approach that grouped the 201 adult foods into the 12 dietary categories used in the previous FDA Total Diet Study food list, for the purpose of estimating the amount of cadmium in the typical U.S. diet (Flynn, 1981). This was necessary because metal analyses for foods on the revised food list were not then available, and still are not. These twelve categories include several to which uptake data may be applied (such as grains and cereals, potatoes, leafy vegetables) and therefore can be used to estimate the impacts of sludge application on contaminant amounts in the diet. However, the individual foods were not broken down according to their contents; for example, beef and vegetable stew was listed in the "meat, fish and poultry" group.

In addition, some of the listed items consist largely of added water, such as canned, reconstituted bouillon (also listed under "meat, fish and poultry"). Therefore, the resulting consumption values for each still did not reflect the raw commodities.

A second approach was presented in the draft Air Quality Criteria Document for Lead (U.S. EPA, 1984b). Here many of the individual foods from the Pennington (1983) diet were fractionally apportioned into different food groups. For example, the food item "pancakes" was apportioned as follows: 60% food crops, 10% dairy and 30% meat, representing the contribution from grains, milk and eggs, respectively. However, the number of food groups employed was too few for use with the present methodology; that is, all crops were lumped into a single category. In addition, the apportionments were made not on the basis of weight of each ingredient as desired for this analysis, but on the basis of the amount of lead in each ingredient.

Therefore, a new analysis of the Pennington (1983) diet was required for this methodology. Each item in the Pennington diet (including the infant/junior foods) was broken down into its components based on information available in FDA (1982) and USDA (1975). The percentages of dry matter and fat for each component were also listed. These components were then aggregated into the specific commodity groups required for this methodology. A summary of consumption for each category by each age/sex group is presented in Table 4-2. Data for the entire analysis are compiled in Appendix 1.

The consumption values from the Pennington (1983) diet, and therefore from Table 4-2 as well, are average values based on 24-hour recall by surveyed individuals. Additional statistics indicating the range of consumption values for the populations studied would also be useful for indicating ranges of exposure; this information was not given, however. Yost and Miles (1980) reanalyzed data from a 1965-1966 USDA survey of food consumption and

TABLE 4-2

Average Daily Dry-Weight Consumption of Food Groups, Based on a Reanalysis of the FDA Revised Total Diet Food List*

Food Group (subgroup)	Consumption by Age-Sex Group (g dry weight/day)							
	6-11 Months	2 Years	14-16 Years		25-30 Years		60-65 Years	
			Females	Males	Females	Males	Females	Males
Grains and cereals								
wheat	27.6020	42.2344	61.5025	97.2110	52.8166	78.5058	45.8331	64.4170
corn	3.9986	15.3541	18.5795	27.8431	13.8710	21.7827	12.3873	17.2590
rice	2.2249	4.5845	5.1368	6.6381	4.7765	6.7825	4.0244	4.3960
oats	3.7298	2.6502	1.0994	2.6740	1.0900	1.5519	1.8611	2.1391
other grain	0.0106	0.0771	0.1022	1.3660	2.8673	24.0360	0.8504	7.9668
Potatoes	5.6673	10.0335	15.9724	22.8305	13.2108	21.3447	12.0376	17.5425
Leafy vegetables	0.8380	0.4854	1.1341	1.2970	2.1703	2.1527	2.7815	2.5232
Legume vegetables	3.8094	4.5571	6.3902	10.5176	7.8752	11.7527	8.1826	10.8195
Root vegetables	3.0400	0.6678	1.3125	2.1398	1.5157	2.0296	1.5110	1.7705
Garden fruits	0.6650	1.6690	3.0740	3.8632	4.1004	5.4053	4.5935	5.1207
Peanuts	0.3363	2.2082	1.7821	4.0428	1.5396	3.3153	1.3398	2.4798
Mushrooms	0.0001	0.0127	0.0551	0.0320	0.1374	0.1355	0.0508	0.0705
Vegetable oil	27.6209	17.6867	30.2176	44.5719	29.7018	44.7022	23.7050	31.9650
Meats								
beef	3.9890	9.6621	16.6613	26.5872	17.3708	29.1939	14.1238	22.5623
beef fat	2.4448	6.4794	12.5395	19.8966	13.8234	26.5786	10.7518	17.3979
beef liver	0.1666	0.2401	0.2766	0.4363	1.2309	0.9214	0.9639	1.4427
beef liver fat	0.0455	0.0656	0.0756	0.1193	0.3364	0.2518	0.2634	0.3943
lamb	0.1393	0.0768	0.0618	0.0439	0.3317	0.2600	0.2110	0.2134
lamb fat	0.1443	0.0795	0.0640	0.0455	0.3435	0.2693	0.2185	0.2210
pork	1.3382	4.2907	7.4094	10.3101	7.0893	13.4471	7.5549	12.3284
pork fat	2.0059	8.1900	10.2186	15.2742	9.7095	19.2524	9.9596	16.1116
poultry	2.2693	3.7573	6.3271	7.7314	6.1537	9.1333	6.2793	7.4611
poultry fat	1.0957	0.8319	1.2237	1.5970	1.2416	1.8352	1.2157	1.3982
fish (including fat)	0.3387	1.2005	2.5395	2.6764	3.5013	4.6697	3.6293	4.1075
Dairy	40.6970	32.9356	34.0111	53.0223	22.5046	32.5447	19.3580	25.4705
dairy fat	38.9867	16.4844	18.7030	30.1483	15.1627	22.7856	12.2980	16.7264
Eggs	3.2709	6.9135	6.0974	8.9355	6.6567	10.0347	7.1952	11.4666
Other	78.8062	67.7638	85.1162	127.2669	80.8883	105.5348	78.6520	94.0083

*Source: Based on Pennington, 1983 and FDA, 1982 presented cumulative-percent distributions of consumption for six food groups. These data, shown in Table 4-3, were also from a survey of 24-hour consumption recall. The data show that for each of six food groups, consumption at the 95th percentile exceeds the mean by a factor ranging from 3.6 (potatoes) to 7.5 (root vegetables).

These factors indicate interindividual variability on a given sampling day. To estimate the interindividual variability in long-term average intake, intraindividual variability over several sampling days must be known. Sempos et al. (1985) have shown that the ratio of intraindividual to interindividual variability (as expressed by the ratio of the variances) is >1 for a variety of dietary parameters. For example, the ratios for four elements (Ca, Fe, Mg, Zn) were 1.2, 2.6, 1.3 and 2.4, respectively. This would seem to indicate that the variability associated with 1-day consumption is greater than that for long-term consumption. Therefore, the 95th and 99th percentile values given in Table 4-3 overestimate those values for long-term consumption. Another limitation of these higher percentile values is that they cannot simply be summed to predict total dietary response, since no single individual would be likely to consume all affected food items in 95th- or 99th-percentile amounts. Matrix methods, or stochastic methods such as Monte Carlo analysis, would be required for combining these values to estimate total dietary intakes representative of the 95th or 99th percentile (Yost et al., 1980).

Vegetarians have been viewed as a group possibly at higher risk from land application practices. Ryan et al. (1982) showed that under certain assessment scenarios, cadmium intake of lacto-ovo-vegetarians could be about 50% higher than that of the population as a whole. This was determined by comparing the Loma Linda lacto-ovo-vegetarian (LOV) diet (Loma Linda University, 1978) with the 1974 FDA Total Diet (after adjustment of the latter to

TABLE 4-3

Distribution of Daily Consumption of Six Food Groups from a Survey Using 24-Hour Recall[a]

Food Group	Consumption (g/day, fresh weight)							
	15- to 20-year-old Males				Entire Population			
	Mean	50%[b,c]	95%[b]	99%[b]	Mean	50%[b,c]	95%[b]	99%[b]
Leafy vegetables	55.1	0	260	440	52.3	0	240	440
Legume vegetables	56.4	0	280	505	44.3	0	245	425
Root vegetables	32.0	0	240	320	37.1	0	250	525
Potatoes	151.8	85	570	1035	101.2	<35	400	685
Garden fruits	84.6	0	520	1900	108.6	0	400	1600
Grains and cereals	160.4	91	570	985	121.6	70	440	695

[a] Source: Yost and Miles, 1980; based on a reanalysis of a USDA survey conducted in 1965-1966

[b] Percentile values, estimated from frequency histograms

[c] Median (50th percentile) values were zero when at least half of the surveyed individuals did not consume items from that group in the preceding 24 hours.

a comparable caloric basis). Consumption data from the LOV diet (as reported by Ryan et al., 1982) are presented in Table 4-4. Comparison of the LOV data with fresh-weight consumption data for 25- to 30-year-old males from Appendix 1 shows that LOV consumption is substantially higher for several vegetable crop categories and lower for potatoes.

The Pennington (1983) data base is more adequate for most features of this analysis. Therefore, the Pennington data, as reanalyzed here (Table 4-2), will be employed in the following criteria derivation procedures. If desired, the results may be adjusted to reflect the LOV diet by adjusting the dry-weight consumption values for these categories by the ratio of the fresh-weight values shown in Table 4-4.

4.1.5. Health Effects in Humans. An adjusted reference intake (RIA, in µg/day) will be defined as the increase in dietary intake of a contaminant that is used to evaluate the potential for adverse effects on human health as a result of land application of sewage sludge. That is, given the practice definitions and assumptions stated previously in this methodology, the criterion for a given sludge contaminant is that concentration in the sludge, or that application rate to land, which is calculated to result in dietary intakes not exceeding the RIA in exposed individuals. To exceed the RIA would be a basis for concern that adverse health effects may occur in those individuals.

The RIA is termed "adjusted" because it is a health-based reference intake value that has been adjusted from a per-weight basis to a particular human body weight and also to account for contaminant intake from other sources.

The procedure for determining RIA varies according to whether the pollutant acts by a threshold or nonthreshold mechanism of toxicity.

TABLE 4-4

Food Consumption of Lacto-Ovo-Vegetarians[a] and Average 25- to 30-Year-Old Males (selected values)[b]

Food Group	Consumption (g/day fresh weight)	
	Lacto-Ovo-Vegetarians	25- to 30-Year-Old Males
Dairy products	584	--
Grains and cereals	203	193
Potatoes	43	68
Leafy vegetables, root vegetables and garden fruits	252	107
Legume vegetables	166	50
Fruits	284	--
Oily fats, shortening	107	--
Sugars and adjuncts	110	--
Beverages	600	--
Meat, fish and poultry	0	--

[a] Source: Loma Linda University, 1978

[b] Source: Pennington, 1983, as reanalyzed in Appendix 1 (see Table A1-2)

4.1.5.1. THRESHOLD-ACTING TOXICANTS -- Threshold effects are those for which a safe (subthreshold) level of toxicant exposure can be estimated. For these toxicants, RIA is derived as follows:

$$RIA = [(RfD \times bw/RE) - TBI] \times 10^3 \tag{4-14}$$

where:

RIA = adjusted reference intake (μg/day)

RfD = reference dose (mg/kg/day)

bw = human body weight (kg)

TBI = total background intake rate of pollutant (mg/day) from all other sources of exposure

RE = relative effectiveness of ingestion exposure (unitless)

10^3 = conversion factor (μg/mg)

The definition and derivation of each of the parameters used to estimate RIA for threshold-acting toxicants are further discussed in the following sections.

4.1.5.1.1. Reference Dose (RfD) -- When toxicant exposure is by ingestion, the threshold assumption has traditionally been used to establish an "acceptable daily intake," or ADI. The Food and Agricultural Organization and the World Health Organization have defined ADI as "the daily intake of a chemical which, during an entire lifetime, appears to be without appreciable risk on the basis of all the known facts at the time. It is expressed in milligrams of the chemical per kilogram of body weight (mg/kg)" (Lu, 1983). Procedures for estimating the ADI from various types of toxicological data were outlined by the U.S. EPA in 1980 (Federal Register, 1980). More recently the Agency has preferred the use of a new term, the "reference dose," or RfD, to avoid the connotation of acceptability, which is often controversial.

Values of RfD for noncarcinogenic or systemic toxicity have been derived by several groups within the Agency. An effort is currently under way to corroborate these values and to produce a master list of RfDs for use by the various Agency programs. Most of the noncarcinogenic chemicals that currently are candidates for sludge criteria for the land application food chain pathways are included on the Agency's RfD list, and thus no new effort will be required to establish RfDs for deriving sludge criteria. For any chemicals not so listed, RfD values should be derived according to established Agency procedures (U.S. EPA, 1987b).

4.1.5.1.2. Human Body Weight (bw) -- The choice of body weight for use in risk assessment depends on the definition of the individual at risk, that in turn depends on exposure and susceptibility to adverse effects. The RfD (or ADI) was defined before as the dose on a body-weight basis that could be safely tolerated over a lifetime. Food consumption on a body-weight basis is substantially higher for infants and toddlers than for teenagers or adults. Certain behaviors, such as mouthing of dirty objects or direct ingestion of soil, which could also contribute to exposure, are also much more prevalent in children than adults. Therefore, infants and toddlers would be at greater risk of exceeding an RfD when exposure is by food or soil ingestion. However, the effects on which the RfD is based may occur after a cumulative exposure period, in some instances approaching the human lifespan. In these cases, it may be reasonable to base the derivation of criteria upon adult values of bw. In cases where effects have a shorter latency (<10 years) and where children are known to be at special risk, it may be more appropriate to use values for toddlers or infants.

4.1.5.1.3. Total Background Ingestion Rate of Pollutant (TBI) -- It is important to recognize that sources of exposure other than the sludge reuse or disposal practice may exist, and that the total exposure should be maintained below the RfD. Other sources of exposure include background levels (whether natural or anthropogenic) in drinking water, food or air. Other types of exposure that are due to occupation or habits such as smoking might also be included depending on data availability and regulatory policy. These exposures are summed to estimate TBI.

Data for estimating background exposure usually are derived from analytical surveys of surface, ground or tap water, from FDA market basket surveys and from air-monitoring surveys. These surveys may report means, medians, percentiles or ranges, as well as detection limits. Estimates of TBI may be based on values representing central tendency or on upper-bound exposure situations, depending on regulatory policy. Data chosen to estimate TBI should be consistent with the value of bw. Where background data are reported in terms of a concentration in air or water, ingestion or inhalation rates applicable to adults or children can be used to estimate the proper daily background intake value. Where data are reported as total daily dietary intake for adults and similar values for children are unavailable, conversion to an intake for children may be required. Such a conversion could be estimated on the basis of relative total food intake or relative total caloric intake between adults and children.

As stated in the beginning of this subsection, the TBI is the summed estimate of all possible background exposures, except exposures resulting from a sludge disposal practice. To be more exact, the TBI should be a summed total of all toxicologically effective intakes from all nonsludge exposures. To determine the effective TBI, background intake values (BI) for each exposure route must be divided by that route's particular relative effectiveness (RE) factor. Thus, the TBI can be derived after all the background exposures have been determined, using the following equation:

$$\text{TBI (mg/day)} = \frac{\text{BI (food)}}{\text{RE (food)}} + \frac{\text{BI (water)}}{\text{RE (water)}} + \frac{\text{BI (air)}}{\text{RE (air)}} + \ldots + \frac{\text{BI (n)}}{\text{RE (n)}} \qquad (4\text{-}15)$$

where:

TBI = total background intake rate of pollutant from all other sources of exposure (mg/day)

BI = background intake of pollutant from a given exposure route, indicated by subscript (mg/day)

RE = relative effectiveness, with respect to dietary exposure, of the exposure route indicated by subscript (unitless)

When TBI is subtracted from the weight-adjusted RfD, the remainder (after adjusting for RE) defines the increment that can result from sludge disposal without exceeding the threshold. If upper-bound data (such as 95th percentiles) were used to estimate TBI, then an increase in exposure corresponding to this increment, if realized, would cause the RfD to be approached or exceeded in a relatively small percentage (5%) of the exposed population. If central-tendency data (the median) were used to estimate TBI, such an increase would cause the RfD to be approached or exceeded in about half of the exposed population. If TBI were set at zero for lack of exposure data, the allowed increase resulting from sludge disposal would result in an unknown degree of exceeding the RfD, depending on whether other sources of exposure exist.

4.1.5.1.4. Relative Effectiveness of Exposure (RE) -- RE is a unitless factor that shows the relative toxicological effectiveness of an exposure by a given route when compared with another route. The value of RE may reflect observed or estimated differences in absorption between the inhalation and ingestion routes that can then significantly influence the quantity of a chemical that reaches a particular target tissue, the length of time it takes to get there, and the degree and duration of the effect. The RE factor may also reflect differences in the occurrence of critical toxicological effects at the portal of entry. For example, carbon tetrachloride and chloroform were estimated to be 40 and 65% as effective, respectively, by inhalation as by ingestion based on absorption differences (U.S. EPA, 1984e,f). In addition to route differences, RE can also reflect differences in bioavailability due to the exposure matrix. For example, absorption of nickel ingested in water has been estimated to be 5 times that of nickel ingested in diet (U.S. EPA, 1985d). The presence of food in the gastrointestinal tract may delay absorption and reduce the availability of orally administered compounds, as demonstrated for halocarbons (NRC, 1986).

Physiologically based pharmacokinetic (PB-PK) models have evolved into particularly useful tools for predicting disposition differences due to exposure route differences. Their use is predicated on the premise that an effective (target-tissue) dose achieved by one route in a particular species is expected to be equally effective when achieved by another exposure route or in some other species. For example, the proper measure of target-tissue dose for a chemical with pharmacologic activity would be the tissue concentration divided by some measure of the receptor binding constant for that chemical. Such models account for fundamental physiologic and biochemical parameters such as blood flows, ventilatory parameters, metabolic capacities and renal clearance, tailored by the physicochemical and biochemical properties of the agent in question. The behavior of a substance administered by a different exposure route can be determined by adding equations that describe the nature of the new input function. Similarly, since known physiologic parameters are used, different species (e.g., humans vs. test species) can be modeled by replacing the appropriate constants. It should be emphasized that PB-PK models must be used in conjunction with toxicity and mechanistic studies to relate the effective dose associated with a certain level of risk for the test species and conditions to other scenarios. A detailed approach for the application of PB-PK models for derivation of the RE factor is beyond the scope of this document, but the reader is referred to the comprehensive discussion in NRC (1986). Other useful discussions on considerations necessary when extrapolating route to route are found in Pepelko and Withey (1985) and Clewell and Andersen (1985). Since most exposures in this group of pathways occur by food consumption, the RE factors applied are all with respect to ingestion in food.* Therefore, the value of RE in Equation 4-14 gives the relative effectiveness of the exposure route and circumstances on which the RfD was based when compared with food. Similarly, the RE factors in Equation 4-15 show the relative effectiveness, with respect to exposure in food, of each background exposure route and matrix.

An RE factor should be applied only where well documented/referenced information is available on the contaminant's observed relative effectiveness or its pharmacokinetics. When such information is not available, RE is equal to 1.

4.1.5.2. CARCINOGENS -- For carcinogenic chemicals, the Agency considers the excess risk of cancer to be linearly related to dose (except at high dose levels) (Federal Register, 1986a). The threshold assumption, therefore, does not hold, as risk diminishes with dose but does not become zero or background until dose becomes zero.

The decision whether to treat a chemical as a threshold- or nonthreshold-acting (carcinogenic) agent depends on the weight of the evidence that it may be carcinogenic to humans. Methods for classifying chemicals as to their weight of evidence have been described by the U.S. EPA (Federal

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*The only exception is exposure from soil ingestion. In this case RE values should take into account the soil matrix if supporting data are available.

Register, 1986a), and most of the chemicals that presently are candidates for sludge criteria have recently been classified in Health Assessment Documents or other reports prepared by the U.S. EPA's Office of Health and Environmental Assessment (OHEA), or in connection with the development of Recommended Maximum Contaminant Levels (RMCLs) for drinking water contaminants (Federal Register, 1985). To derive values of RIA, a decision must be made as to which classifications constitute sufficient evidence for basing a quantitative risk assessment on a presumption of carcinogenicity. Chemicals in classifications A and B, "human carcinogen" and "probable human carcinogen," respectively, have usually been assessed as carcinogens, whereas those in classifications D and E, "not classifiable as to human carcinogenicity because of inadequate human and animal data" and "evidence of noncarcinogenicity for humans," respectively, have usually been assessed according to threshold effects. Chemicals classified as C, "possible human carcinogen," have received varying treatment. For example, lindane, classified by the Carcinogen Assessment Group (CAG) of the U.S. EPA as "B2-C," or between the lower range of the B category and category C, has been assessed both by using the linear model for tumorigenic effects (U.S. EPA, 1980b) and based on threshold effects (Federal Register, 1985). Table 4-5 gives an illustration of these EPA classifications based on the available weight of evidence.

The use of the weight-of-evidence classification, without noting the explanatory material for a specific chemical, may lead to a flawed conclusion since some of the classifications are exposure route dependent. Certain compounds or elements, such as nickel, have been shown to be carcinogenic by the inhalation route but not by ingestion (U.S. EPA, 1985d). Similarly, arsenic has been shown to cause carcinogenic effects when certain inorganic forms are ingested in water, but no carcinogenic

TABLE 4-5

Illustrative Categorization of Carcinogenic Evidence
Based on Animal and Human Data*

Human Evidence	Animal Evidence				
	Sufficient	Limited	Inadequate	No Data	No Evidence
Sufficient	A	A	A	A	A
Limited	B1	B1	B1	B1	B1
Inadequate	B2	C	D	D	D
No data	B2	C	D	D	E
No evidence	B2	C	D	D	E

*The above assignments are presented for illustrative purposes. There may be nuances in the classification of both animal and human data indicating that different categorizations than those given in the table should be assigned. Furthermore, these assignments are tentative and may be modified by ancillary evidence. In this regard all relevant information should be evaluated to determine if the designation of the overall weight of evidence needs to be modified. Relevant factors to be included along with the tumor data from human and animal studies include structure-activity relationships, short-term test findings, results of appropriate physiological, biochemical and toxicological observations, and comparative metabolism and pharmacokinetic studies. The nature of these findings may cause an adjustment of the overall categorization of the weight of evidence.

potential has been demonstrated for the organic forms normally present in many foods (U.S. EPA, 1984a). The issue of whether or not to treat an agent as carcinogenic by ingestion remains controversial for several chemicals.

If a pollutant is to be assessed according to nonthreshold, carcinogenic effects, the adjusted reference intake, RIA (in µg/day), is derived as follows:

$$RIA = \left[\left(\frac{RL \times BW}{q_1^* \times RE}\right) - TBI\right] \times 10^3 \qquad (4\text{-}16)$$

where:

RIA = adjusted reference intake (µg/day)

q_1^* = human cancer potency [(mg/kg/day)$^{-1}$]

RL = risk level (unitless) (e.g., 10^{-5}, 10^{-6}, etc.)

BW = human body weight (kg)

RE = relative effectiveness of ingestion exposure (unitless)

TBI = total background intake rate of pollutant (mg/day); from all other sources of exposure

10^3 = conversion factor (µg/mg)

The RIA, in the case of carcinogens, is thought to be protective recognizing that the estimate of carcinogenicity is an upper limit value. The definition and derivation of each of the parameters used to estimate RIA for carcinogens are further discussed in the following sections.

4.1.5.2.1. Human Cancer Potency (q_1^*) -- For most carcinogenic chemicals, the linearized multistage model is recommended for estimating human cancer potency from animal data (Federal Register, 1986a). When epidemiological data are available, potency is estimated based on the observed relative risk in exposed vs. nonexposed individuals, and on the magnitude of exposure. Guidelines for use of these procedures have been presented in the Federal Register (1980, 1985) and in each of a series of

Health Assessment Documents prepared by OHEA (such as U.S. EPA, 1985c). The true potency value is considered unlikely to be above the upper-bound estimate of the slope of the dose-response curve in the low-dose range, and it is expressed in terms of risk-per-dose, where dose is in units of mg/kg/day. Thus, q_1* has units of $(mg/kg/day)^{-1}$. OHEA has derived potency estimates for each of the potentially carcinogenic chemicals that currently are candidates for sludge criteria. Therefore, no new effort will be required to develop potency estimates to derive sludge criteria.

4.1.5.2.2. Risk Level (RL) -- Since by definition no "safe" level exists for exposure to nonthreshold agents, values of RIA are calculated to reflect various levels of cancer risk. If RL is set at zero, then RIA will be zero. If RL is set at 10^{-6}, RIA will be the concentration that, for lifetime exposure, is calculated to have an upper-bound cancer risk of one case in one million individuals exposed. This risk level refers to excess cancer risk, that is, over and above the background cancer risk in unexposed individuals. By varying RL, RIA may be calculated for any level of risk in the low-dose region, that is, RL $\leq 10^{-2}$. Specification of a given risk level on which to base regulations is a matter of policy. Therefore, it is common practice to derive criteria representing several levels of risk without specifying any level as "acceptable."

4.1.5.2.3. Human Body Weight (bw) -- Considerations for defining bw are similar to those stated in Section 4.1.5.1.2. The CAG assumes a value of 70 kg to derive unit risk estimates for air or water. As discussed previously, ingestion exposures may be higher in children than in adults when expressed on a body-weight basis. However, if exposure is lifelong, values of bw are usually chosen to be representative of adults.

4.1.5.2.4. Total Background Intake Rate of Pollutant (TBI) -- As discussed in Section 4.1.5.1.3., it is important to recognize that sources of exposure other than the sludge reuse disposal practice may exist. The total exposure to a given pollutant should be maintained below the determined cancer risk-specific exposure level (RL).

4.1.5.2.5. Relative Effectiveness of Ingestion Exposure (RE) -- In some cases potency estimates have been derived on the basis of a different type of exposure than may occur from food-chain contamination. In these cases, the use of RE for carcinogens is similar to that described earlier for threshold-acting toxicants (see Section 4.1.5.1.4.). As stated in that section, an RE factor should only be applied where well documented/referenced information is available on the contaminant's observed relative effectiveness or its pharmacokinetics. When such information is not available, RE is equal to 1.

4.2. SLUDGE-SOIL-PLANT-HUMAN TOXICITY EXPOSURE PATHWAY

4.2.1. Assumptions. In addition to many of the assumptions listed in Table 4-1, some additional assumptions relating to relative uptake response of crop food groups and percent of diet affected by sludge application are made for this pathway. These assumptions and their potential ramifications are summarized in Table 4-6 and further discussed in the following text.

4.2.2. Calculation Method.

4.2.2.1. CATEGORY 1 CONTAMINANTS --

4.2.2.1.1. Procedure Based on Curvilinear ("Plateau") Uptake Response Model and Relative Uptake Response Values -- Criteria for inorganic pollutant concentrations in sludge applied to land where crops for human consumption are grown may be calculated using a curvilinear response model and relative response values, if sufficient data are available. The procedure

TABLE 4-6

Assumptions for Sludge-Soil-Plant-Human Toxicity Exposure Pathway

Functional Area	Assumptions	Ramifications/Limitations
Relative uptake response of crop food groups	The response of crops in a given food group (such as legume vegetables) can be represented by a single value (or in some cases two values) selected based on the available response data for crops in the group.	Variability of crop response (and therefore dietary response) may be underestimated, especially where few data are available.
Fraction of diet affected by sludge application	The percentage of commercially distributed foods in an individual's diet that derives from sludge-amended soil can be estimated as a function of regional sludge production, regional cropland area, agronomic sludge application rates and percentage of sludge typically applied to human food-chain land.	The size of the region over which foods are mixed is not well defined. Sludge-amended lands may enter or leave production of human food-chain crops. Sludge management practices may shift in response to regulations or other factors.
	All of an individual's homegrown food could come from sludge-amended soil.	May overpredict exposure.
	The percentage of homegrown food in the diet of the MEI can be estimated from USDA (1966) survey data on rural farm households, which constituted 6% of all households.	More recent information, if available, might show significant changes in both demographics and gardening habits of these households.

for deriving criteria for a given contaminant is summarized in Table 4-7 and described in detail as follows:

Step A. Determine Relative Uptake Response Values for Each Crop

Relative response values for the metal at hand should be determined for as many crops as permitted by the available data. As discussed in Section 4.1.2.1., relative response is determined within and not across studies and is determined with respect to an index crop that is both sensitive (in terms of response) and frequently studied. (Lettuce is an example of a crop often meeting these criteria.) The index crop should also be one for which data showing a plateau are most widely available (see Step D). A relative response value for crop A would be determined as follows:

$$RU_{AI} = \frac{UC_A}{UC_I} \qquad (4\text{-}17)$$

where:

RU_{AI} = uptake response for crop A relative to index crop (unitless)

UC_A = linear uptake response slope of crop A (μg/g [kg/ha]$^{-1}$)

UC_I = Linear uptake response slope of index crop in the same experiment in which UC_A was measured

Some studies (Davis and Carlton-Smith, 1980; Carlton-Smith and Davis, 1983) showing the response of multiple crops to different sludge-amended soils do not report contaminant application rates and, therefore, values of the linear response slope UC cannot be calculated. However, if tissue levels for crops A and I were both measured in two different soils, then RU_{AI} can be estimated as follows:

$$RU_{AI} = \frac{A_2 - A_1}{I_2 - I_1} \qquad (4\text{-}18)$$

TABLE 4-7

Summary of Criteria Derivation Procedure Based on Curvilinear Uptake Response Model and Relative Uptake Response Values

Step	Description	Text Page
A	Determine relative uptake response values for each crop	4-43
B	Determine relative uptake response values for each food group	4-45
C	Determine the reference tissue concentration increment (RTI) for the index crop	4-46
D	Sort available uptake response data for the index crop	4-47
E	Determine plateau increment values (PI) for the index crop	4-48
F	Determine reference sludge concentration (RSC) not causing reference tissue concentration increment (RTI) to be exceeded	4-48
G	Check the reference sludge concentration (RSC) by substituting other crops for the index crop	4-49

where A_2 denotes tissue concentration of crop A in soil 2, and so forth. As a practical matter, this procedure should only be used when it is clear from the data that the contaminant concentration is substantially higher in soil 2 than in soil 1, so that the difference between I_2 and I_1 is meaningful. A control soil, if used, is the best choice for soil 1. This procedure was used in U.S. EPA (1987a).

Uptake response relative to the index crop should be determined for as many crops as possible. Where more than one relative response value can be determined for one crop, a value determined under high-response conditions (such as at low pH) should ordinarily be selected as a conservative measure. If a given crop (A) has not been studied in the same experiment as the index crop (I), but has been co-studied with another crop (B) for which response relative to the index (RU_{BI}) has been determined, relative response for crop A (RU_{AI}) can be estimated as follows:

$$RU_{AI} = RU_{BI} \times RU_{AB} \qquad (4\text{-}19)$$

where RU_{AB} is uptake response of crop A relative to crop B.

Step B. Determine Relative Uptake Response Values for Each Food Group

Once relative response has been determined for as many crops as possible, these crops should be divided into the crop food groups shown in Table 4-2. A single relative response value should be assigned to each food group in most instances. This value may be determined as a weighted mean of all the available response values where weighting is according to the dry-weight consumption of each crop. Where there are no response values for a particular crop, care should be taken in assigning values so that the response value is from a closely related crop. If the data do not permit determination of a weighted mean, an unweighted mean may be taken, or to be conservative the highest single value may be chosen to represent that food group.

If the data indicate that a food group consists of some crops that are relatively high accumulators and some that are relatively low (such as lettuce, spinach and chard vs. cabbage and the other coles in the leafy vegetable food group), then it may be worthwhile to subdivide the food group on this basis. If no relative response value can be determined for a particular food group, the highest value for any of the other comparably responsive food groups should be assigned to that group.

Step C. Determine the Reference Tissue Concentration Increment (RTI) for the Index Crop

Once a relative response value has been determined for each food group potentially affected by sludge application, the response values are coupled with the dry-weight consumption values for each group. In this manner, total dietary response to sludge application can be related to the response of the index crop. A reference tissue concentration increment (RTI, in µg/g DW) based on human health effects and fraction of diet affected can then be determined for the index crop:

$$RTI = \frac{RIA}{\sum_{i=1}^{n} (RU_i \times DC_i \times FC_i)} \qquad (4\text{-}20)$$

where:

RIA = adjusted reference intake (µg/day)

RU_i = relative uptake response for ith food group (unitless)

DC_i = daily dietary consumption of ith food group (g DW/day)

FC_i = fraction of food group assumed to originate from sludge-amended soil (unitless)

Reference intake, RIA, is derived based on health effects data as discussed in Section 4.1.5. RTI, as derived from Equation 4-20, is the tissue concentration increase for the index crop that, if exceeded, indicates that the health-based intake level used to derive RIA will be exceeded.

Step D. Sort Available Uptake Response Data for the Index Crop

The available response data for the indicator crop should be grouped according to whether soil pH was <6.0 or $\geq$6.0, and according to whether the plateau was observed in the first year of sludge application or over several years. If criteria are to be derived based on the assumption (or the requirement) that pH will be maintained $\geq$6.0 in sludge-amended soils where food crops are grown, then studies with pH <6.0 should not be used for derivation of criteria. If soil pH will not necessarily be maintained $\geq$6.0, then studies with pH <6.0 should be used as a conservative measure, since these studies normally show higher metal uptake. This procedure differs from the existing approach (40 CFR 257.3-5) of using pH 6.5 as the cutoff between different permissible application rates. The Las Vegas workshop report (U.S. EPA, 1987) concludes that plant response to metals is not significantly increased when the soil pH (as determined using a 1:1 soil-water suspension) decreases from 6.5 to 6.0 (although it may increase at pH <6.0). The report further concludes that the use of soil cation exchange capacity (C.E.C.) as a basis for determining metal application limits is not supported by current evidence. Therefore, no difference in approach based on C.E.C. is recommended here. The use of this methodologic approach should be conditioned upon acceptance of the final workshop report by the workshop participants and other scientists knowledgeable in this field.

That report also indicates that data based on the first year of sludge application will tend to show higher response rates and higher plateau values than data from annually repeated sludge additions. It is unlikely that any individual would be exposed, year after year, to crops grown immediately following a first application of sludge, and therefore basing risk assessments solely on first-year data may be unreasonable. On the other hand, some exposure to such crops would presumably occur. In the case of chronic exposure this would not be a problem. However, for acute exposure, separate criteria calculations should be carried out based on first-year and multi-year application to determine the potential range of results.

Step E. Determine Plateau Increment Values (PI) for the Index Crop

All available response data in the index crop for the metal at hand for the groups identified in Step D should be examined to determine which studies show a plateau for tissue concentration. As suggested earlier (see Section 4.1.2.1.2.), the plateau value (P, in μg/g DW) may be determined using nonlinear regression and estimation of confidence limits around the asymptote. A value derived from P will be used in subsequent calculations, e.g., the plateau increment value, PI (in μg/g DW), which is the plateau value (P) minus the background tissue concentration (BC) for the experiment in which P was determined.

Step F. Determine Reference Sludge Concentration (RSC) Not Causing Reference Tissue Concentration Increment (RTI) to be Exceeded

For each grouping of plateau data described in Step D above, it should be determined whether a reference sludge concentration (RSC) can be identified that gives a plateau increment (PI) not exceeding the RTI. To make such a determination, several steps are necessary. First, it must be demonstrated that all sludges with metal concentration at or below the RSC always result in tissue concentration increments below the RTI in all available sludge-field studies within that grouping, regardless of the sludge (or contaminant) application rate. This finding must hold true in studies that do not show a plateau, as well as those that do. Second, an adequate number of studies must be available to clearly demonstrate the relationship between sludge concentration and plateau increment (PI), so that there can be a high degree of confidence that the use of a different sludge or soil will not result in exceeding the RTI. This methodology will not attempt to define the number or quality of studies necessary to make this determination; the validity of a derived value of RSC should be determined by expert peer review.

Studies at soil pH <6.0 may be used to help validate an RSC for soil pH ≥ 6.0, but the reverse does not apply. Similarly, first-year studies may be used to validate an RSC for multi-year applications, but the reverse should not be done.

Step G. Check the Reference Sludge Concentration (RSC) by Substituting Other Crops for the Index Crop

According to the relative response hypothesis, it should be possible to use any crop as the index crop and arrive at about the same value for RSC. Thus, RSC can be checked against other crops, even if plateau data are not available for those crops. To do so, RTI_S for the substitute crop is first determined as follows:

$$RTI_S = RTI_I \times RU_{SI} \tag{4-21}$$

where:

RTI_S = reference tissue concentration increment for substitute crop (µg/g DW)

RTI_I = reference tissue concentration increment for index crop (µg/g DW)

RU_{SI} = uptake response in substitute crop relative to index crop (unitless)

Steps D-F are then repeated using data for the substitute crop. If data showing a plateau are not found, it can still be determined from the available data whether application of sludge at or below RSC ever results in tissue concentration increments exceeding RTI_S. If so, RSC should be revised downward so that RTI_S is not exceeded.

RSC should be tested in this manner using all crops for which RU has been determined. If RU for a given food group was derived as a weighted mean (see Step B, above), then RTI_S may be exceeded for certain crops in that food group. However, the following condition should hold:

$$\frac{TI_S}{RTI_S} \leq \frac{RU_S}{RU_G} \qquad (4\text{-}22)$$

where:

TI_S = highest tissue concentration increment (i.e., increase above background) observed in substitute crop when sludge having concentration ≤RSC was applied (μg/g DW)

RU_S = relative uptake response value in substitute crop (unitless)

RU_G = relative uptake response value of food group to which substitute crop belongs (unitless)

In other words, the degree to which RTI_S is exceeded should not be greater than the degree to which RU_S exceeds RU_G. If Equation 4-22 holds, then the lesser degree of response by other foods in that food group has been assumed to counterbalance the higher response in that particular crop. If Equation 4-22 does not hold, RSC must be revised downward.

Once the above steps have been followed, RSC represents a sludge concentration that can be applied repeatedly where crops for human consumption are grown. The relationship between the experimental basis for RSC and the resulting sludge application rules is illustrated in Table 4-8. If only first-year data were used in Steps E-G, then no annual or cumulative contaminant application limit need be applied to sludges with metal concentration at or below the value of RSC for that particular metal. If multi-year data were used (without support from first-year data; see Step F), then no cumulative application limit is needed for sludges meeting RSC, but annual application rates for the metal should not exceed the rates used in the

TABLE 4-8

Relationship Between the Experimental Basis for Reference Sludge Concentration (RSC) and Rules Governing Use of Sludges Meeting RSC*

Data Used To Generate Limit	Soil pH ≥6.0 and/or <6.0	 <6.0 only
Multi-year and/or first-year	A	B
First-year only	C	D

A. Applies to cumulative application if soil pH will remain ≥6.0 without liming. Separate, annual application limit applies.

B. Applies to cumulative application. The pH requirement is dependent upon data. Separate, annual application limits apply.

C. Applies to cumulative application if soil pH will remain ≥6.0 without liming. Separate, annual application limit not required.

D. Applies to cumulative application. The pH requirement is dependent upon data. Separate, annual application limit not required.

*For explanation, see text.

studies in which RSC was determined. That is, even though annual applications of sludge with a concentration of metal X of 10 µg/g never caused RTI to be exceeded when 10 t DW/ha of sludge was applied over several years, it cannot be assumed that a single application of 50 t DW/ha will not cause it to be exceeded. Therefore, an annual contaminant application limit of (10 t DW/ha x 10 µg/g) 0.1 kg/ha should apply in this case, although no cumulative limit is needed. Alternatively, the annual application limit may be based on the procedure using the linear model (see Section 4.2.2.1.2.).

When crops for human consumption are grown on agricultural lands that have received sludge, liming is often practiced to maintain soil pH ≥6.0 so as to lessen uptake of metals. However, it cannot be assumed that liming will continue after the land is sold to another farmer or developed for residential use, since there is no requirement that future owners be informed of sludge applications. Therefore, it is recommended that criteria based in whole or in part on data from soils of pH ≥6.0 be employed only where soils are expected to remain at pH ≥6.0 even when liming is not practiced. Similarly, if RSC is derived using data from soils at pH >6.0, sludges meeting this RSC value could be applied without cumulative application limits as long as soil pH was expected to remain ≥6.0. If based only on soils with pH <6.0, the pH requirement would be that of the data used. For example, if the pH of the study used was 5.5 there would be a pH 5.5 requirement.

4.2.2.1.2. **Procedure Based on Linear Uptake Response Model and Relative Uptake Response Values** -- Criteria based on the assumption of linear uptake (as opposed to curvilinear uptake) will also be required for use in the following situations: 1) if the available data are insufficient to support derivation of RSC values; 2) if RSC for acid soils cannot be derived and pH maintenance is not viable; or 3) to govern application of sludges that do not meet RSC. The criteria derivation procedure based on linear uptake is summarized in Table 4-9 and described in detail in later sections.

Step A. Determine Relative Uptake Response Values for Each Crop

This step is the same as described for the curvilinear model procedure in Section 4.2.2.1.1.

Step B. Determine Relative Uptake Response Values for Each Food Group

This step is the same as described for the curvilinear model procedure in Section 4.2.2.1.1.

Step C. Determine the Reference Tissue Concentration Increment (RTI) for the Index Crop

This step is the same as described for the curvilinear model procedure in Section 4.2.2.1.1.

Step D. Sort Available Uptake Response Data for the Index Crop

This step is the same as described for the curvilinear model procedure in Section 4.2.2.1.1.

Step E. Determine Appropriate Uptake Response Slopes for the Index Crop

The highest valid uptake slope for each of the categories established in Step D should be identified. That is, field studies where sludge was applied should be considered to provide the most valid information; pot studies with sludge should be used where the latter are not available. Pot studies with added metal compounds are considered less useful, even if sludge was also applied. It should be realized from previous discussion (Section 4.1.2.1.1.) that pot studies will overestimate plant response in field situations.

TABLE 4-9

Summary of Criteria Derivation Procedure Based on Linear Uptake Response Model and Relative Uptake Response Values

Step	Description	Text Page
A	Determine relative uptake response values for each crop	4-53
B	Determine relative uptake response values for each food group	4-53
C	Determine the reference tissue concentration increment (RTI) for the index crop	4-53
D	Sort available uptake response data for the index crop	4-53
E	Determine appropriate uptake response slopes for the index crop	4-53
F	Determine reference application rate of the pollutant (RP)	4-55
G	Check the reference application rate of the pollutant (RP) by substituting other crops for the index crop	4-55
H	Adjust the reference application rate of the pollutant (RP) for phytotoxic effects	4-55

Step F. Determine Reference Application Rate of the Pollutant (RP)

For each category established in Step D, the reference application rate of the pollutant (RP, in kg/ha) is calculated from the reference tissue concentration increment (RTI, in µg/g DW) and the index crop response slope (UC_I, in µg/g DW $[kg/ha]^{-1}$), as follows:

$$RP = RTI/UC_I \qquad (4\text{-}23)$$

This is analogous to the determination of a reference sludge concentration (RSC) in Step F of the curvilinear model method (see Section 4.2.2.1.1.) except that instead of a plateau, that relates tissue concentration increment to a sludge concentration, a slope is used that relates the tissue concentration increment to a pollutant application rate.

Step G. Check the Reference Application Rate of the Pollutant (RP) by Substituting Other Crops for the Index Crop

This step is analogous to Step G of the previous section (see Section 4.2.2.1.1.). A reference tissue concentration increment for a substitute crop is determined using Equation 4-21. Using response slopes for the substitute crop from the appropriate category established in Step D, RP is recalculated from Equation 4-23. Studies at soil pH <6.0 may be used to help validate an RP value for soil pH $\geq$6.0, but the reverse does not apply. Similarly, first-year studies may be used to validate RP for multi-year applications, but the reverse should not be done. If the recalculated RP is less than RP based on the index crop, the recalculated value should be used, except when Equation 4-22 holds true.

Step H. Adjust the Reference Application Rate of the Pollutant (RP) for Phytotoxic Effects

Since the linear uptake model projects continually increasing tissue concentrations with increasing pollutant application, it is possible using this model to predict increases in tissue concentration that in actuality would be prevented by toxic effects in the plant. If so, the application rate calculated in the soil-plant pathway (see Section 4.6) will be lower than that calculated in the present pathway, and therefore adjustments to the rate calculated here may be unnecessary. However, an adjustment method will be presented so that each pathway may stand alone and to avoid overestimating the potential for human health effects from phytotoxic pollutants.

A maximum pollutant application rate (RPM_i) based on phytotoxicity should be determined for each crop group that was used in Steps B and C to help determine RTI:

$$RPM_i = (TL_i - BC_i)/(RU_i \times UC_I) \qquad (4\text{-}24)$$

where:

TL_i = maximum tissue concentration for crop category i, above which crop production is virtually eliminated by phytotoxicity (μg/g DW)

BC_i = background concentration for crop category i (μg/g DW)

RU_i = relative uptake response value for crop category i (unitless)

UC_I = uptake response slope for index crop, used to determine the RP value being adjusted (μg/g DW $[kg/ha]^{-1}$)

The calculated RPM_i represents the pollutant application rate at which, according to the linear response model, the tissue concentration in crop category i reaches its maximum level; higher concentrations would effectively terminate crop production. Values of RPM_i are compared with RP. If $RPM_i < RP$, then crop i is assumed to remain at and not exceed a concentration of TL_i. This relationship is illustrated in Figure 4-3. [Note that tissue concentration is not assumed to drop to zero, which would indicate effective removal of crop i from the diet. Since RP is a permitted, but not required, application rate, is is assumed that lower rates would be used on more sensitive crops.]

For all crops for which RPM_i <RP, tissue concentration is no longer related to application rate; Equation 4-20 is therefore changed to the following:

$$RTI = \frac{RIA - \sum_{j=1}^{n} [(TLj-BCj) \times DCj \times FCj]}{\sum_{k=1}^{n} (RU_k \times DC_k \times FC_k)} \qquad (4\text{-}25)$$

where subscript j indicates those crop categories for which RPM_i <RP, and subscript k indicates those for which RPM_i ≥RP. Thus, the summation in the numerator has units of µg/day and denotes the constant amount of contaminant in the diet contributed by those crops assumed to be at their maximum concentration. This amount is subtracted from the adjusted reference intake, RIA, to determine the remaining intake amount that can be partitioned into those crops still uptake-dependent in the denominator.

If Equation 4-25 is used, RTI will increase, since uptake response has been limited in some crop categories. Therefore, RP will also increase (from Equation 4-23), and may exceed RPM_i for additional crops, requiring additional recalculation of RTI using Equation 4-25. This iterative process is repeated until there is no further change in RP.

Once the above steps have been followed, RP represents a cumulative application rate for inorganic pollutants that should not be exceeded where crops for human consumption are grown. As was the case when the curvilinear response model was used (see Section 4.2.2.1.1.), the interpretation of RP depends on the data used in its derivation (see Step D above). If only first-year data were used in Steps E-G, then RP constitutes a cumulative limit. If multi-year data were used (with or without support from first-year data, see Step G), RP is a cumulative rate limit, but may not be fully protective in the first year of application. RP based on first-year data could be used as an annual limit.

If derived using data from soils at pH ≥ 6.0 (with or without support from data derived at pH <6.0), RP is a cumulative application limit for soils expected to remain at or above that pH value. If based only on studies with pH <6.0, then RP is a cumulative application limit that can be applied to all soils, regardless of pH. The relationship between the experimental basis for RP and the resulting rules is illustrated in Table 4-10.

4.2.2.1.3. Procedure Based on Linear Uptake Response Model Without Using Relative Uptake Response Values -- Criteria are calculated using this procedure if relative response values cannot be determined for an adequate number of crops to characterize the various affected food groups. Instead of relative uptake response values, which are unitless, absolute uptake response slopes, in units of $\mu g/g$ DW $(kg/ha)^{-1}$, are used to determine dietary response to the sludge-borne contaminant. The main disadvantage of using slopes is that the slopes for each crop used will likely originate from different experimental conditions. To examine total dietary response to a change in conditions (such as soil pH), all of the response slopes need to be changed, instead of individually examining the change in response of an index crop and several substitute crops as can be done using relative response values. The use of the curvilinear model is also precluded in practical terms. The steps for this procedure are summarized in Table 4-11 and are described in detail below.

TABLE 4-10

Experimental Basis for the Reference Application Rate of Pollutant (RP) and Situations Where RP Applies*

Data Used To Generate Limit	Soil pH	
	≥6.0 and/or <6.0	<6.0 only
Multi-year and/or first-year	A	B
First-year only	C	D

A. Applies to cumulative application if soil pH will remain ≥6.0 without liming. Separate, annual application limit applies.

B. Applies to cumulative application. The pH requirement is dependent upon data. Separate, annual application limits apply.

C. Applies to cumulative application if soil pH will remain ≥6.0 without liming. Separate, annual application limit not required.

D. Applies to cumulative application. The pH requirement is dependent upon data. Separate, annual application limit not required.

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*For explanation, see text.

TABLE 4-11

Summary of Criteria Derivation Procedure Based on Linear Uptake Response Model Without Using Relative Uptake Response Values

Step	Description	Text Page
A	Sort available uptake response data for all food crops	4-61
B	Determine uptake response slopes for each food group	4-61
C	Determine reference application rate of the pollutant (RP)	4-61
D	Adjust the reference application rate of the pollutant (RP) for phytotoxic effects	4-62

Step A. Sort Available Uptake Response Data for All Food Crops

The data for all crops consumed by humans are sorted as described in Step D of the previous procedures (see Sections 4.2.2.1.1. and 4.2.2.1.2.).

Step B. Determine Uptake Response Slopes for Each Food Group

This step is analogous to that described in Step B of the previous procedures except that response slopes, with units of µg/g DW $(kg/ha)^{-1}$, are substituted for unitless response values. For each food group, a separate response slope should be derived for each of the categories established by sorting in Step A. However, as described in Step F of the curvilinear procedure (see Section 4.2.2.1.1.) and Step G of the linear procedure using relative response values (see Section 4.2.2.1.2.), studies at pH <6.0 may be used to augment the data for pH $\geq$6.0, and first-year studies may be used to augment the data for multi-year studies, but the reverse should not be done.

Step C. Determine Reference Application Rate of the Pollutant (RP)

Since there is no index crop, a reference tissue concentration is not calculated. Instead, the reference application rate of the pollutant (RP, in kg/ha) is calculated directly from the response data by the following equation:

$$RP = \frac{RIA}{\sum_{i=1}^{n} (UC_i \times DC_i \times FC_i)} \qquad (4\text{-}26)$$

where:

RIA = adjusted reference intake (µg/day)

UC_i = uptake response slope for ith food group (µg/g DW $[kg/ha]^{-1}$)

DC_i = daily dietary consumption of ith food group (g DW/day)

FC_i = fraction of food group assumed to originate from sludge-amended soil (unitless)

Step D. Adjust the Reference Application Rate of the Pollutant (RP) for Phytotoxic Effects

This step is identical to Step H of the linear procedure using relative response values (see Section 4.2.2.1.2.) except that, instead of first recalculating RTI (see Equation 4-25) before recalculating RP, RP is calculated directly from the following equation:

$$RP = \frac{RIA - \sum_{j=1}^{n} [(TLj - BCj) \times DCj \times FCj]}{\sum_{k=1}^{n} (UC_k \times DC_k \times FC_k)} \qquad (4\text{-}27)$$

where subscript j indicates those food groups for which $RPM_i < RP$, and subscript k indicates those for which $RPM_i \geq RP$. RPM_i values are calculated as in Equation 4-24, except that UC_I must be substituted for the quantity $RU_I \times UC_I$. The interpretation of values of RP derived by this procedure is as illustrated in Table 4-10.

4.2.2.2. CATEGORY 2 CONTAMINANTS -- The criteria derivation procedure for organic contaminants by the sludge-soil-plant-human toxicity pathway is largely the same as the procedure for inorganics based on the linear response model and not using relative response values (see Section 4.2.2.1.3. and Table 4-11). One difference is that uptake data are not segregated on the basis of either soil pH or years of sludge application, since no reason for doing so has been demonstrated. In addition, the procedure for calculating response slopes for organics differs somewhat from that for inorganics, in that tissue concentration is treated as a linear function of soil concentration rather than application rate, as explained in Section 4.1.2.2. Thus, Equations 4-26 and 4-27 yield a reference concentration in soil (RLC) in µg/g DW, rather than the reference application rate of pollutant, RP, in kg/ha. This assumes that the soil background concentration, BS, is zero. If BS≠0, then Equations 4-26 and 4-27 yield RLC-BS. That is, BS must be added to the result to derive RLC.

RLC is the soil concentration that should not be exceeded. The value of RLC may be used in Equation 4-13, along with values for degradation rate constant in soil (k, in years^{-1}), waiting period before planting (T, in years), and assumed annual sludge application rate (AR_a, in t DW/ha), to find RP_a, the annual application rate of the pollutant (in kg/ha). RP_a is the application rate that can be repeated indefinitely without exceeding RLC. If only a single sludge application is to be made, the single application rate of the pollutant, RP_{sT} (in kg/ha), is derived from Equation 4-6. The preplant waiting period, T, may be employed if desired.

4.2.3. Input Parameter Requirements. The following sections discuss in more detail the individual parameters required to calculate criteria for the sludge-soil-plant-human toxicity pathway. In many cases the assignment of parameter values depends on the specific type of land application practice assumed. As explained in Chapters 2 and 3, it is assumed that all lands other than dedicated land and highway roadsides can eventually become agricultural land or home gardens. Therefore, this methodology will not make distinctions between the risks associated with various sludge utilization practices; only the practices with highest risk need be examined. However, it is difficult to state _a priori_ whether application to agricultural lands or home gardens entails the highest risk. A home gardener may grow a high percentage of certain types of foods, but a wider number of food types would probably be affected by agricultural use. Therefore, both of these exposure scenarios should be examined to determine for each contaminant of concern that entails the higher risk. The resulting restrictions should be applied to all lands except dedicated lands and highway roadsides.

No special consideration will be given to hothouse or other indoor crop production except to examine potential risk from any crops grown only in that setting. The only such crop not already covered under the home garden or agricultural use scenarios is mushrooms. An analysis of contaminant uptake data for mushrooms should be conducted to determine whether precautions based on other crops will be sufficient to prevent any excessive accumulations. For example, Logan and Chaney (1983) presented a review of data showing particularly high uptake of mercury by mushrooms. They suggested that sludge composts might not be suitable for use in mushroom production. Parameter choices are discussed below and also are summarized in Table 4-12 for agricultural and home gardening practices where crops for human consumption are grown.

4.2.3.1. FRACTION OF FOOD GROUP ASSUMED TO ORIGINATE FROM SLUDGE-AMENDED SOIL (FC) -- This exposure pathway deals with crops for human consumption and thus potentially includes grains and cereals, potatoes, leafy vegetables, legume vegetables, root vegetables, garden fruits, peanuts and mushrooms (see Table 4-2). Some food groups might be assumed to be unaffected by certain sludge application practices; in these cases, FC would be set at zero. For food groups that may be affected, FC is set between zero and one, based on the percentage likely to have originated from sludge-amended soils.

4.2.3.1.1. Agricultural Utilization -- Sludge production in the United States is not sufficient to enable application to all U.S. cropland (Table 4-13). Therefore, not all of the U.S. diet will be affected, even if

TABLE 4-12

Choice of Input Parameter Values for Sludge-Soil-Plant-Human Toxicity Pathway, As Affected by Exposure Scenario*

Input Parameter	Exposure Scenario	
	Agricultural Use	Home Garden
Crops included	all except mushrooms	all except grains and cereals, peanuts, mushrooms
Fraction of crop (FC)	0.025	0.60 vegetables 0.45 potatoes 0.17 dried legumes

*For explanation, see text.

TABLE 4-13

Human Population, Sludge Production, Cropland and Cropland Required Annually for the Application of Sewage Sludge in Illinois, New Jersey and the United States in 1970, and projected values for 1985[a]

Area	Population (millions)	Sludge Produced (thousands of metric tons)	Cropland[b] (thousands of hectares)	Cropland Required for Indicated Sludge: Sludge Containing 1% avail. N: Thousands of Hectares	Cropland Required for Indicated Sludge: Sludge Containing 1% avail. N: % of Total Cropland	Cropland Required for Indicated Sludge: Sludge Containing 4% avail. N: Thousands of Hectares	Cropland Required for Indicated Sludge: Sludge Containing 4% avail. N: % of Total Cropland
1970							
Illinois	11.14	197	9,242	17.4	0.19	70.5	0.76
New Jersey	7.20	127	170	11.3	6.68	45.4	26.71
USA	203.90	3602	131,548	322.0	0.24	1287.7	0.98
1985							
Illinois	12.56	390	8,586	34.8	0.38	139.3	1.51
New Jersey	8.49	264	166	23.5	13.83	94.0	55.34
USA	234.50	7278	126,526	650.0	0.49	2560.0	1.98

[a] Source: CAST, 1976

[b] Harvested cropland in 1975. The total surface areas in Illinois, New Jersey and the United States are 14.62, 2.03 and 937.05 million hectares, respectively

N = Nitrogen

all sludge produced were applied to agricultural soils. However, the degree to which any individual's diet will be affected will depend on the degree of mixing of food products before consumption. If mixing were complete on a nationwide basis, FC for the individual's overall diet could not exceed the fraction of cropland available in the United States that would be required to receive all sludge produced (assuming that fertilization/irrigation achieves equivalent yields where sludge is not used). Table 4-13, taken from CAST (1976), illustrates the percentage of total available cropland that would be required, based on nitrogen content, to dispose of the total sludge production for the entire United States. Estimates for 1985 (based on 1975 information) ranged from 0.49 to 1.98%. If mixing were complete only on a more geographically limited basis, such as statewide, the fraction could be much higher, especially in areas where available cropland is small compared with population size (such as 55% for New Jersey). It is quite unlikely that all crops consumed in any state, especially a highly urbanized one, would originate within that state. However, it may be insufficiently conservative to assume complete mixing nationwide. If an average of the U.S. and New Jersey cases based on 4% available nitrogen is taken, a somewhat arbitrary value of 29% results.

Not all of the sludge produced is presently land applied, and the percent applied to human food-chain land is lower (16%) for large treatment plants [>10 million gallons/day (MGD); characteristic of population centers] than for small plants (31% for plants <1 MGD; characteristic of rural areas). A weighted average of 17% applies to all sludge produced (Pierce and Bailey, 1982).

It may be desirable to base values of FC on a more recent and thorough regional analysis of sludge application, land use and food distribution practices, as well as sludge nitrogen content. No such analysis will be attempted here. For purposes of example only, a value of 5% or 0.05 (~0.29x0.17) will be employed here as a reasonable worst-case estimate. The use of this value of FC for all food groups will tend to overestimate exposure, since not all sludge-grown crops are for human consumption. For example, livestock feed, export and seed uses of grain produced in the United States exceed the amounts used directly for human food products (CAST, 1976). Thus, a value of 2.5% could be employed as a worst case estimate of FC for crops grown for human consumption.

4.2.3.1.2. Home Gardens -- It will be assumed that home gardeners produce and consume potatoes, leafy vegetables, legume vegetables, root vegetables and garden fruits, but not grains and cereals, peanuts or mushrooms. The USDA (1966) survey of U.S. food consumption in 1965-1966 includes data on the percentages of foods consumed that were homegrown, for urban, rural nonfarm and rural farm households. The highest percentages of homegrown foods were for rural farm households, which consitituted ç6% of all U.S. households (Table 4-14). The rural farm dweller will be taken as the MEI for the home gardening scenario in this pathway. Values of FC (after rounding) are 0.60 for all vegetables (except dried legumes), 0.45 for potatoes and 0.17 for dried legumes.

4.2.3.2. UPTAKE RESPONSE DATA: RELATIVE UPTAKE RESPONSE VALUE (RU), PLATEAU INCREMENT VALUE (PI) AND UPTAKE RESPONSE SLOPE (UC) -- Uptake response data are required for as many crops as possible in the food groups for which FC≠0, as determined in the previous section. Instructions for deriving the needed uptake parameters are given previously: for RU see Section 4.1.2.1. and Step A of 4.2.2.1.1.; for PI see Section 4.1.2.1.2. and Step E of 4.2.2.1.1.; and for UC see Section 4.1.2.1.1.

TABLE 4-14

Annual Consumption Homegrown Foods[a,b]

Food Group	Percent Homegrown by Urbanization		
	Rural Farm	Rural Nonfarm	Urban
Milk, cream, cheese	39.9	4.0	0.04
Fats, oil	15.2	1.6	0
Flour, cereal	1.6	0.8	0
Meat	44.2	6.1	0.8
Poultry, fish	34.3	11.9	2.9
Eggs	47.9	9.1	0.6
Sugar, sweets	9.0	5.0	1.6
Potatoes, sweet potatoes	44.8	14.6	1.2
Vegetables (fresh, canned, frozen)	59.6	26.7	5.1
Fruit (fresh, canned, frozed)	28.6	11.5	2.8
Juice (vegetable, fruit)	11.0	4.1	0.7
Dried vegetables, fruits	16.7	6.9	2.6

[a] Source: Calculated from data presented in USDA (1966)

[b] The percentage of the U.S. population represented by households from each urbanization at the time of this survey were 6%, 24% and 70% for rural farm, rural nonfarm and urban, respectively.

Response slope (UC) or plateau increment value (PI) for many contaminants varies inversely with soil pH and number of years of previous sludge applications (or years since most recent application). The following assumptions should be applied when selecting response data to represent different types of land application. Soil pH may be controlled ($\geq$6.0) or uncontrolled (possibly <6.0, as determined using a 1:1 soil-water paste) in agricultural utilization. Therefore, both situations should be evaluated to determine whether pH control is warranted. However, pH control should not be assumed in home gardens; studies with soil pH <6.0 should be used to determine UC or PI. In agriculture and home gardening, crops may be grown in the first year of sludge application. Therefore, data of this type should be used to determine annual application limits, but data based on prior sludge applications (or intervening years without sludge application) may be used to determine cumulative limits. For site-specific calculations, if future use of land may include raising food crops but present use does not, then first-year response data should be avoided.

4.2.3.3. DAILY DIETARY CONSUMPTION OF FOOD GROUP (DC) -- Values for daily dietary consumption (DC, in g DW/day) are needed for each food group for which FC$\neq$0. The values chosen should be appropriate for the MEI, an individual with higher than average intake of the affected food groups. Consumption data presented in Pennington (1983) and reanalyzed in Table 4-2 are mean values for each of eight age/sex groups. One could define the MEI in terms of the age/sex group having the highest consumption for all of the food groups combined, or for each individual food group. Alternatively, one could estimate a 95th-percentile consumption level based on variability of 1-day consumption; however, this procedure risks overestimation of long-term consumption. The appropriate use of dietary data to characterize the MEI is more fully discussed in Section 4.1.4.

4.2.3.4. BACKGROUND CONCENTRATION IN CROPS (BC) -- Background concentration data are required for index crops (BC_I) and substitute crops (BC_S) used to determine the plateau increment, PI (see Section 4.2.2.1.1., Step E). Whenever possible, values for BC_I should be taken from the study used to determine the plateau value, P, and reference sludge concentration, RSC. Values for BC_S should be taken from each study used to check RSC.

Background data are also required whenever a maximum pollutant application rate based on phytotoxicity (RPM) is calculated (see Section 4.2.2.1.2., Step H). If possible, BC should be taken from the same study from which TL was derived (see Section 4.2.3.5.).

4.2.3.5. MAXIMUM TISSUE CONCENTRATION (TL) -- TL is the tissue concentration limit, above which crop production is virtually eliminated by phytotoxicity. TL is used as a limit to linear response, as explained in Section 4.1.2.1.1. The maximum pollutant application rate based on phytotoxicity (RPM) must be calculated for each food crop. If a given crop was used to determine the linear response slope, UC, for a food group, then TL for the same crop should be used, if possible, to calculate RPM. If the same crop cannot be used, or if UC was based on a weighted mean, then TL should be based on that crop for which the highest tissue TL value is found.

4.2.3.6. WAITING PERIOD (T) -- If a waiting period (T, in years) occurs following the last sludge application before crops are grown, the value of RP_a for organic compounds will increase. (Refer to Section 4.1.1. for methods of calculating RP_a from RLC.) Ordinarily, no waiting period is assumed. However, current regulations [40 CFR 257.3-6(b)(3)] call for a waiting period of 1.5 years if the sludge has not been treated by a "process to further reduce pathogens" (PFRP) and if crops that contact the sludge are grown. It is suggested that values of $T = 1.5$ years and $T = 0$ years be used for comparison when deriving criteria for land application practices for this exposure pathway. For D&M practices, $T = 0$ should be assumed.

4.2.3.7. ADJUSTED REFERENCE INTAKE (RIA) -- Values for adjusted reference intake (RIA, in µg/day) are derived based on health effects data, as described in Section 4.1.5.

4.3. SLUDGE -- HUMAN TOXICITY (SOIL INGESTION) EXPOSURE PATHWAY

4.3.1. Assumptions. In addition to many of the assumptions listed in Table 4-1, some additional assumptions are made for this pathway relating to the degree of sludge ingestion that could occur and the method of assessing potential effects. These assumptions and their potential ramifications are summarized in Table 4-15 and are further discussed in the following sections.

4.3.2. Calculation Method. A reference soil concentration (RLC, in µg/g DW) may be determined based on human health effects data, as follows:

$$RLC = RIA/(I_s \times DA) \qquad (4\text{-}28)$$

where:

RIA = adjusted reference intake (µg/day)
I_s = soil ingestion rate (g DW/day)
DA = exposure duration adjustment (unitless)

The procedure for ensuring that RLC will not be exceeded depends on whether or not the sludge is soil-incorporated. If it is not, then it will be assumed that the uppermost soil layer, which children may ingest, is 100% sludge. Therefore, sludge concentration should be controlled. If soil incorporation is practiced, then pollutant application rate is the basis for criteria calculation. For organic compounds, soil degradation must also be

TABLE 4-15

Assumptions for Sludge-Human Toxicity (Soil Ingestion) Exposure Pathway

Functional Area	Assumption	Ramifications/Limitations
Exposure assessment	D&M sludge is not necessarily soil-incorporated; children may be exposed to the undiluted product.	Overestimates exposure in situations where soil incorporation of D&M products is practiced.
	Soil incorporation prior to exposure of children is assumed for all land application practices; children are not exposed to the undiluted product.	Could underestimate exposure only if young children have daily access to sludge application areas, such as forests or pastures, where soil incorporation is not practiced.
	Sludge, or sludge-amended soil, may be ingested by children at the rates observed in studies of pica for soil.	Overestimates exposure to the extent that the pica child frequents some areas where sludge has not been applied.
Effects assessment	It is assumed that pica may occur from 1 to 6 years of age. Cancer potency is adjusted to reflect a 5-year rather than 70-year exposure.	If the child is more susceptible to chemical carcinogenesis than the adult, a 5/70 adjustment could result in underestimation of hazard.

taken into account. Equations relating soil concentrations to sludge application rates, with and without degradation, are presented in Section 4.1.1.

4.3.2.1. SURFACE APPLICATION -- It is assumed that surface application, without soil incorporation, may occur for many D&M sludge uses. These practices could result in exposure of children, either immediately or following land-use conversion. The calculations for determining the reference sludge concentration, RSC (in µg/g DW) are as follows.

4.3.2.1.1. Inorganics -- Since degradation ordinarily is not assumed, the reference sludge concentration, RSC, is equal to RLC.

4.3.2.1.2. Organics -- If immediate exposure potential exists following application, the procedure for organics is the same as for inorganics. This assumption is followed for the purposes of deriving criteria, since conversion periods are neglected (see Chapter 3). In some instances, however, it may be desirable to assume a land-use conversion period (T, in years) before exposure of children is likely. Since degradation may occur, the initial soil concentration prior to conversion, RLC_o, is calculated from RLC by the following equation, which is derived from Section 4.1.1.2., Equation 4-4:

$$RLC_o = RLC \times e^{kT} \qquad (4\text{-}29)$$

The reference sludge concentration, RSC, is then set equal to RLC_o.

4.3.2.2. SOIL INCORPORATION -- Soil incorporation is required in agricultural utilization when crops for human consumption are grown, and such a requirement will be evaluated for pasture lands as well (see Section 2.2.1.2.). If agricultural, forest or reclaimed lands are converted to residential use, it is assumed that soil incorporation will occur during the process of land conversion, if it has not already occurred. The reference application rate of the pollutant (RP, in kg/ha) is determined from RLC as described in Section 4.1.1., using Equation 4-3 for inorganics, and Equation 4-6 or 4-13 for organics, for single or multiple applications, respectively.

4.3.3. Input Parameter Requirements.

4.3.3.1. SOIL INGESTION RATE (I_s) -- Soil ingestion has been recognized as an important source of exposure to pollutants such as lead. For adults, a value of 0.02 g/day has been used to estimate dust ingestion (U.S. EPA, 1984b). Children may ingest soil by either inadvertent hand-to-mouth transfer or by intentional direct eating. When such behavior is frequent, it is called pica. Lepow et al. (1975) estimated that children frequently mouthing their hands may inadvertently ingest at least 100 mg of soil per day. Studies aimed at more accurately determining the range of ingestion rates have yielded some data but are as yet inconclusive. Binder et al. (1986) conducted a pilot study to establish methods for determining soil ingestion rates in children living near a lead smelter. Three tracer elements, aluminum, silicon and titanium, were measured in soil and dust samples and in stool samples of 70 children. Results for the three elements were often in disagreement, indicating either a metabolic loss or unrecognized sources of one or more of the elements.

Assuming that the lowest estimate for a given child was accurate, and that the higher estimates for the other two elements represented sources other than soil, the following results were obtained (in g DW/day): for 59 children with soil and stool measurements, mean ingestion was 0.108; the median was 0.088; the geometric mean was 0.065; the range was 0.004-0.708 and the 95th percentile was 0.386 (Table 4-16).

Estimates based on aluminum and silicon were possibly the most accurate, since these were in relatively close agreement, and the titanium results should probably be dismissed as anomalous (since these averaged higher by a

TABLE 4-16

Various Estimates of Daily Soil Ingestion in Children of Ages 1-3*

Element	Number of Children	Daily Soil Ingestion (g/day)					
		Mean	Median	Geometric Mean	S.D.	Range	95th Percentile
Element producing lowest estimate	59	0.108	0.088	0.065	0.121	0.004-0.708	0.386
Aluminum	65	0.181	0.121	0.128	0.203	0.025-1.324	0.584
Silicon	65	0.184	0.136	0.130	0.175	0.031-0.799	0.578
Titanium	65	1.834	0.618	0.401	3.091	0.004-17.076	9.590

*Source: Binder et al., 1986

factor of 10). This assumption produces slightly higher estimates, as shown in Table 4-16. Based on these preliminary data, a value of 0.5 g/day is suggested as a reasonably protective value for I_s. Further studies are being undertaken by the U.S. EPA to improve these estimates.

4.3.3.2. ADJUSTED REFERENCE INTAKE (RIA) -- Values for adjusted reference intake (RIA, in μg/day) are derived based on health effects data, as described in Section 4.1.5. Some special provisions may apply, since this exposure occurs only in children (1-6 years of age).

4.3.3.2.1. **Human Body Weight (bw)** -- A body weight of 10 kg, the approximate median body weight at 12 months of age, should be used.

4.3.3.2.2. Total Background Ingestion Rate of Pollutant (TBI) -- The value of TBI should be based on a body weight of 10 kg. FDA data for infants/toddlers may be available; otherwise it is suggested that ingestion amounts be adjusted downward. A factor of 3 is suggested for such an adjustment. TBI should not include pollutant ingestion in soil, since the background concentration in soil is handled separately in Equation 4-3.

4.3.3.3. EXPOSURE DURATION ADJUSTMENT (DA) -- An adjustment to the RIA may be required based on the brief duration of this exposure. Values of RfD and q_1* are usually calculated to be representative of a lifetime exposure. Adjustment of RfD values for exposure duration is not recommended because higher exposures may lead to more severe toxic effects. However, time adjustment of cancer risk estimates is consistent with the method in which potency estimates (q_1*) are derived, and has been used previously. Therefore, a DA value is suggested for use with carcinogenic chemicals. The value is derived on the basis of exposure duration divided by assumed lifetime, or 5 years/70 years = 0.07. This adjustment should be carefully evaluated on a case-by-case basis to ensure that an exposure of RIA/DA will not lead to toxic effects other than carcinogenesis.

4.4. EXPOSURE PATHWAYS FOR HERBIVOROUS ANIMALS FOR HUMAN CONSUMPTION

4.4.1. Assumptions. Animal forage may be contaminated by uptake of sludge pollutants through the plant roots (sludge-soil-plant-animal-human toxicity) or by adherence of sludge to plant surfaces or roots [sludge-animal (direct ingestion) human toxicity]. As explained in Section 3.1.3., soil incorporation is not assumed when sludge is applied to pasture, and direct ingestion may occur. Therefore, the criteria calculation procedure should be used to evaluate whether soil incorporation should be required. In forest use, soil incorporation often is not feasible, and direct ingestion is possible by animals such as deer that will be taken by hunters in unsludged areas. Deer and other game may also feed in agricultural areas and be taken and consumed by hunters. However, the amount of game consumed is assumed not to exceed the consumption of home-produced meat by farm dwellers. Therefore, the farm dweller is taken as the MEI. Criteria that protect the MEI are assumed to be protective of hunters as well. It is assumed that sludge application to this farmland may have occurred as a current or previous agricultural application practice, or as a previous forest or disturbed-land application practice. Additional assumptions are listed in Table 4-17. Various aspects of the assessments for these pathways are shown in Table 4-18.

4.4.2. Calculation Method.

4.4.2.1. UPTAKE PATHWAY: SLUDGE-SOIL-PLANT-ANIMAL-HUMAN TOXICITY -- A reference concentration of contaminant in animal feed (RFC, in µg/g DW)

TABLE 4-17

Assumptions for Pathways Dealing with Herbivorous Animals

Functional Area	Assumption	Ramifications/Limitations
Fraction of diet affected by sludge application	The MEI is assumed to be an individual raising much of his own meats, poultry, eggs and dairy products. The percentage of home-produced foods in the diet of the MEI is estimated from a USDA (1966) survey of rural farm households, which constituted 6% of all households.	More recent information, if available, might show significant changes in both demographics and food production habits of these households.
	Individuals consuming wild game that forage in sludged areas are assumed to have no greater exposure than the MEI identified above.	Information to substantiate this assumption is not immediately available
Ingestion by animals of sludge, sludge-amended soil or forage crops	Contaminant uptake by crops may affect all animal feeds, but only grazing animals are affected by adherence.	
	Direct ingestion of sludge occurs only when soil-incorporation is not practiced, and then only animals consuming pasture crops are affected.	
	The linear response slope of the most responsive forage crop is used to represent all forage crops in the animal diet.	Will tend to overpredict average crop response.

TABLE 4-18

Exposure Pathways for Herbivorous Animals for Human Consumption: Effects of Management Practice on Various Parameters[a]

Pathway	Management Practice	Form in Diet	Meats Affected	FA	FL/FS	Form of Criterion
Uptake	row or pasture crops	grain, grass, other animal feeds	beef, lamb, pork	0.44	NA	RP
			dairy	0.40		
			poultry	0.34		
			eggs	0.48		
Adherence	pasture crops, with soil-incorporation	sludge-amended soil and roots	beef, lamb only	0.44	FL=0.10	RP
			dairy	0.40		
	pasture crops, without soil-incorporation	pure sludge on plant surfaces and in thatch layer	beef, lamb only	0.44	FS=0.30 or 0.08[b]	RSC
			dairy	0.40		

[a] For explanation, see text.

[b] Choice of value depends on whether or not a 30-day waiting period is employed before grazing or harvest.

may be calculated based on human health effects data, uptake by animal tissues and consumption of those tissues by humans:

$$RFC = \frac{RIA}{\sum (UA_i \times DA_i \times FA_i)} \tag{4-30}$$

where:

RIA = adjusted reference intake of pollutant in humans (μg/day)

UA_i = uptake response slope of pollutant in the ith animal tissue [μg/g tissue DW $(\mu g/g \text{ feed DW})^{-1}$]

DA_i = daily dietary consumption of ith animal tissue food group (g DW/day)

FA_i = fraction of food group assumed to be derived from sludge-amended soil or feedstuffs

RFC is the increase in feed concentration of the animal's total diet that will cause contaminant intake in exposed individuals to equal the RIA. The actual feed concentration includes background concentration as well and therefore may be higher.

Following the calculation of RFC, the reference application rate of the pollutant (RP, in kg/ha) is calculated. The procedure differs for category 1 and category 2 contaminants, since the units of crop uptake differ.

4.4.2.1.1. Category 1 Contaminants -- For inorganics that are conserved in the soil, a cumulative application rate (RP_c, in kg/ha) is calculated:

$$RP_c = RFC/UC \tag{4-31}$$

where:

RFC = reference feed concentration of pollutant (μg/g DW)

UC = linear response slope of forage crop [μg/g crop DW $(\text{kg/ha})^{-1}$]

4.4.2.1.2. Category 2 Contaminants -- For organic compounds and inorganics that are not conserved in the soil, before determining pollutant application rate, a reference soil concentration (RLC, in μg/g DW) is calculated:

$$RLC = (RFC/UC) + BS \tag{4-32}$$

where:

BS = background soil concentration of pollutant (μg/g DW)

UC = linear response slope of forage crop [μg/g crop DW (μg/g soil DW)$^{-1}$]

The procedure for estimating application rate of pollutant, RP, from RLC is given in Equations 4-6 and 4-13 for single and multiple applications, respectively.

4.4.2.2. ADHERENCE PATHWAYS: SLUDGE-ANIMAL (DIRECT INGESTION) -- HUMAN TOXICITY -- The reference feed concentration (RFC, in μg/g DW) is calculated as for the uptake pathway (see Equation 4-30) but the values will differ because fewer human food categories will be affected. If soil incorporation is assumed, the upper parts of crops are assumed to be uncontaminated in agricultural use, and thus only grazing animals (e.g., cattle, sheep) are affected. If soil incorporation is not assumed, the upper parts of pasture crops may be contaminated and may be harvested as feed for cattle or sheep, or they may be grazed directly by these animals. Sludge can also accumulate in the thatch layer of pasture and can be directly consumed by grazing animals. Domestic animals consuming grains or other nonpasture crops (such as pork, poultry) are assumed not to be affected.

4.4.2.2.1. Soil Incorporation of Sludge -- Following the calculation of RFC, RFC is adjusted by the amount of soil in the diet to determine the reference soil concentration (RLC, in μg/g DW):

$$RLC = (RFC/FL) + BS \qquad (4\text{-}33)$$

where:

RFC = reference feed concentration of pollutant (μg/g DW)
FL = fraction of diet that is adhering soil (g soil DW/g diet DW)
BS = background soil concentration of pollutant (μg/g DW)

A pollutant application rate, RP, is calculated from RLC as described in Section 4.1.1. Equation 4-2 or 4-3 is used for inorganics; Equation 4-6 or 4-13 is used for organics.

4.4.2.2.2. Surface Application Without Soil Incorporation -- When sludge is consumed directly from plant or soil surfaces, contaminant intake by the grazing animal is more closely related to sludge concentration than contaminant application rate. Therefore, criteria are derived in terms of a reference sludge concentration (RSC, in μg DW/g) rather than RP. For inorganics and organics, RSC is derived as follows:

$$RSC = \frac{RFC}{FS} \tag{4-34}$$

where:

FS = fraction of animal diet which is sludge (g sludge DW/g diet DW).

If a waiting period (T, in years) is assumed and occurs between the most recent sludge application and grazing, RSC may be multiplied by the expression e^{kT}, where k is the loss rate constant (in $years^{-1}$).

4.4.3. Input Parameter Requirements.

4.4.3.1. FRACTION OF FOOD GROUP ASSUMED TO BE DERIVED FROM SLUDGE-AMENDED SOIL OR FEEDSTUFFS (FA) -- As was the case with FC in the crops-for-human-consumption pathway (see Section 4.2.3.1.), this parameter determines which food groups are included in the analysis.

For the first of these two pathways (sludge-soil-plant-animal-human toxicity), all meat groups except fish will be assumed to be affected. These include beef, lamb, pork, poultry, dairy products and eggs. The second pathway [sludge-animal(direct ingestion)-human toxicity] is assumed to affect only grazing animals; beef, lamb and dairy food groups are included.

As for the pathway dealing with crops for human consumption, the MEI for these two pathways is chosen as a farm family raising a substantial percentage of their own meat and other animal products. The choice of FA values is based on the percentage of homegrown foods consumed by rural farm households (see Table 4-14). These values have been reiterated in Table 4-18. As stated previously, it is assumed that these FA values are sufficiently high that an individual consuming wild game from sludged areas will also be protected.

4.4.3.2. DAILY DIETARY CONSUMPTION OF FOOD GROUP (DA) -- Values for daily dietary consumption (DA, in g DW/day) are needed for each food group for which FA≠0. As was described for DC (see Section 4.2.3.3.), consumption data are taken from Table 4-2 or other information presented in Section 4.1.4. The food item "beef liver" in Table 4-2 includes various other organ meats consumed by humans in smaller amounts, such as kidneys and hearts. Individuals with a preference for those organs are expected to consume them at the rates given for beef liver. It is also assumed that consumption of wild game does not exceed the values of DA for other meats (beef, lamb) and that criteria derivation procedures based on consumption of these meats will also protect hunters.

4.4.3.3. FRACTION OF ANIMAL DIET THAT IS SOIL (FL) OR SLUDGE (FS) -- Studies of grazing animals indicate that soil ingestion ordinarily ranges from 1 to 10% of dry weight of diet (but may range as high as 20%) for cattle and may be 30% or higher for sheep during winter months when forage is reduced (Thornton and Abrams, 1983). Since lamb contributes relatively little to the U.S. diet, a value of FL = 10% or 0.10, based largely on cattle, will be used to represent a reasonably high exposure situation.

Studies of sludge adhesion to growing forage following applications of liquid or filter-cake sludge show that when 3-6 t/ha of sludge solids is applied, clipped forage initially consists of up to 30% sludge on a dry-weight basis (Chaney and Lloyd, 1979; Boswell, 1975). However, this contamination diminishes gradually with time and growth, and generally is not detected in the following year's growth. Where pastures amended at 16 and 32 t/ha were grazed throughout a growing season (168 days), average sludge content of forage was only 2.17 and 5.17%, respectively (Bertrand et al., 1981).

In the draft Las Vegas report, Chaney et al. (1987) review these and other data on sludge adherence to forage crops, and show that by 21-28 days following sludge application, the amount of sludge in or on forage was 0.5-5.4% (DW/DW), depending on the sludge moisture content and forage species. Sludge in the feces of cattle rotationally grazed on these pastures at least 7-21 days following sludge application was slightly higher, as high as 7.7%, probably indicating some ingestion of sludge from the soil surface. Therefore, a value of FS = 30% or 0.30 is recommended if no waiting period is employed before grazing or harvest of sludge-amended pasture. A value of 0.08 is recommended if a waiting period of T = 0.082 years (30 days) is employed.

4.4.3.4. UPTAKE SLOPE OF POLLUTANT IN ANIMAL TISSUE (UA) -- Uptake slopes for affected tissues consumed by humans should be calculated as described in Section 4.1.2.3. The form and availability of uptake response data will affect the types of food groups included in the calculation of RFC (see Equation 4-30) and therefore the choice of values for FA and DA as well. If values of UA can be calculated for several different types of meats (beef muscle, pork muscle, beef liver, etc.), then each of these meats can be separately included in Equation 4-30. If data for only a single type of meat are available, it may be necessary to assume that similar types of meat from different species have similar UA values. These tissues would then be grouped in Equation 4-30. It should not be assumed, however, that organ meats and muscle have similar UA values, since organ meats often accumulate more highly.

This analysis also assumes that UA values for wild game species are no greater than those for the domestic animals to which most available data apply. If data contradicting this assumption are available, these values may be used in Equation 4-30 to calculate RFC.

4.4.3.5. LINEAR UPTAKE RESPONSE SLOPE OF FORAGE CROP (UC) -- The crop chosen for UC should be the one showing the highest response slope appropriate for the exposure scenario involved. Grains, legumes (such as soybeans), silage or grasses could be affected in agricultural use.

4.4.3.6. ADJUSTED REFERENCE INTAKE (RIA) -- Values for RIA (in µg/day) are derived based on health effects data as described in Section 4.1.5.

4.4.3.7. WAITING PERIOD (T) -- If a 30-day waiting period is assumed as discussed previously (see Section 4.4.3.3.), then a value of T = 0.082 years is used in calculations dealing with the nonincorporation scenario (see Section 4.4.2.2.2.).

4.5. EXPOSURE PATHWAYS FOR TOXICITY TO HERBIVOROUS ANIMALS

These two pathways [sludge-soil-plant-animal toxicity; sludge-animal toxicity (direct ingestion)] are similar to the two just discussed. However, since toxicity to the animal itself is now the endpoint of concern, the list of animals to be considered is broadened to include all herbivores found in the agricultural or forest environment. For example, herbivorous rodents or birds should be considered, as well as large herbivores and other domestic animals. However, the pathway for adherence of agricultural soils to plant roots still is limited to grazing animals that ingest significant amounts of soil (cattle, sheep).

4.5.1. Assumptions. The assumptions pertaining to this pathway have been stated in Tables 4-1 and 4-17.

4.5.2. Calculation Method. The calculations for these pathways are the same as given in the previous section, except that a feed concentration corresponding to a toxicity threshold in a sensitive herbivore should be substituted for the reference feed concentration, RFC, in all calculations. Since RFC was defined as the increase in feed concentration resulting in an adverse condition in humans, RFC is redefined for these pathways as follows:

$$RFC = TA - BC \qquad (4\text{-}35)$$

where:

RFC = reference feed concentration (μg/g DW)
TA = threshold feed concentration (μg/g DW)
BC = background concentration in feed crop (μg/g DW)

Equations 4-31 to 4-34 are then used to determine criteria, in the form of either RP or RSC.

4.5.3. Input Parameter Requirements. The focus of the methodology for these pathways is the identification of the appropriate threshold feed concentration, TA. Procedures for selecting TA are generally discussed in Section 4.1.3. An important source of relevant data for inorganic chemicals is found in NRC (1980), "Mineral Tolerances of Domestic Animals." Values of TA are needed for various types of herbivorous animals, including grazing animals, many birds and many small mammals.

4.6. SLUDGE-SOIL-PLANT TOXICITY EXPOSURE PATHWAY

4.6.1. Assumptions.

The assumptions pertinent to this pathway have been stated in Table 4-1.

4.6.2. Calculation Method.

Determination of criteria for this pathway is straightforward, involving few or no calculations. A threshold phytotoxic application rate of the pollutant, TP (in kg/ha), can in some cases be derived directly from phytotoxicity studies. If the pollutant is not subject to loss, then a reference cumulative application rate, RP_c (in kg/ha), is simply

$$RP_c = TP \tag{4-36}$$

If the pollutant is subject to loss from soils, then RP is derived by substituting TP for the expression $RLC \times MS \times 10^{-3}$ either in Equation 4-6, if a single application is to be used, or Equation 4-13, if multiple applications are to be used.

If instead of TP, a value of the threshold phytotoxic soil concentration, RLC (in µg/g DW), is derived, then RP is calculated using either Equation 4-3 (for nondegrading pollutants) or 4-6 or 4-13, as appropriate (for degrading pollutants).

4.6.3. Input Parameter Requirements. The focus of the methodology for this pathway is the selection of the appropriate application rate (TP) or soil concentration (RLC) that corresponds to the threshold level for adverse effects in plants. The threshold is generally defined in Section 4.1.3. as the geometric mean of the lowest exposure level causing, and the highest level not causing, a significant adverse effect. The terms "significant" and "adverse" are further defined in that section.

As for uptake data, it would be preferable to derive these values from sludge application studies conducted in the field. When such data are not available, less appropriate data, such as from greenhouse studies or pesticide application studies, may be used.

Values of TP or RLC may be available for numerous plant species for a given chemical. Ordinarily the recommended procedure is to identify the most sensitive species and ensure that it will be protected by the value selected, unless that species does not grow in the United States (or in a given region, if site-specific criteria are derived).

Phytotoxicity of metals may be altered by soil pH. If TP or RLC values can be segregated based on pH (i.e., ≥ 6.0 or <6.0), then separate criteria can be established on this basis as well. However, criteria based on pH ≥ 6.0 should be applied only where soil pH is expected to remain ≥ 6.0 without addition of lime.

4.7. EXPOSURE PATHWAYS FOR TOXICITY TO SOIL BIOTA AND THEIR PREDATORS

This section deals with two pathways: toxicity to soil biota (sludge-soil-soil biota toxicity) and toxicity to predators of soil biota (sludge-soil-soil biota-predator toxicity). As explained in Section 3.1.6., the term "soil biota" is intended to refer to a broad range of organisms including microorganisms and various invertebrates living in or on the soil. Their predators similarly include a variety of organisms. The availability of data determines what species are considered.

4.7.1. Sludge-Soil-Soil Biota Toxicity Exposure Pathway. Procedures for this pathway are identical to those described above for phytotoxicity (Section 4.6.), except that the threshold levels, TP and RLC, deal with effect thresholds in soil biota rather than in plants. As was touched on in Section 4.1.3., "adverse" effects can be particularly difficult to define where microorganisms are concerned. It is assumed that long-term reductions in soil microbial activity or diversity that can be attributed to the chemical should be considered adverse in lieu of information to the contrary.

4.7.2. Sludge-Soil-Soil Biota-Predator Toxicity Exposure Pathway.

4.7.2.1. ASSUMPTIONS -- In addition to many of the assumptions listed in Table 4-1, some additional assumptions pertinent to this pathway are stated in Table 4-19.

4.7.2.2. CALCULATION METHOD -- Calculations of criteria for this pathway may take either of two forms, depending on the type of data available concerning contaminant uptake by soil biota. If uptake response (that is, the increase of concentration) in soil biota, UB, can be expressed in terms of a pollutant application rate, then criteria are calculated as follows:

$$RP = \frac{TA - BB}{UB} \tag{4-37}$$

where:

RP = reference application rate of pollutant (kg/ha)
TA = threshold feed concentration for the predator (μg/g DW)
BB = background concentration in soil biota (μg/g DW)
UB = uptake response slope in soil biota [μg/g $(kg/ha)^{-1}$]

If the chemical is not subject to degradation or loss in soil, RP is a cumulative rate (RP_c). Otherwise, the value of RP from Equation 4-37 can be substituted for the expression RLC x MS x 10^{-3} in Equation 4-6 to derive a single-application rate, RP_{sT}, or in Equation 4-13 to derive an annual rate, RP_a.

If soil biota response is measured in terms of a soil concentration, as is more often the case, the following equation is used:

$$RLC = \frac{TA - BB}{UB} + BS \tag{4-38}$$

TABLE 4-19

Assumptions for Sludge-Soil-Soil Biota-Predator Toxicity Exposure Pathway

Functional Area	Assumption	Ramifications/Limitations
Contaminant uptake by soil biota	Response in tissues of soil biota can be represented by a linear function.	Probably oversimplifies a more complex relationship.
Use of available data to protect a variety of species	It is assumed that use of the highest available response slope in soil biota and the lowest available dietary threshold in predators will result in protection of untested species.	This conservative assumption could be overprotective of some species; the extent to which it underprotects others is unknown. A "match" of data for a consumed organism and its predator usually is not possible.

where:

RLC = reference soil concentration of pollutant (μg/g DW)
UB = uptake response slope in soil biota [μ/g (μg/g)$^{-1}$]
BS = background soil concentration of pollutant (μg/g DW)

and other parameters are as defined above. RLC is then used in Equation 4-3 (for nondegrading chemicals) or Equations 4-6 or 4-13 (for degrading chemicals), as appropriate.

4.7.2.3. INPUT PARAMETER REQUIREMENTS --

4.7.2.3.1. Threshold Feed Concentrations for the Predator (TA) -- A wide variety of organisms may prey on soil invertebrates, including birds and insectivorous mammals. For a given chemical, information on subchronic or chronic toxicity for oral administration may be available for only a few species, and thus the value chosen for TA may be for a species not actually preying on soil biota. In general, the lowest dietary adverse effect level (and the accompanying no-adverse-effect level) found for birds or small mammals are used to determine the threshold. The threshold is calculated as discussed in Section 4.1.3.

4.7.2.3.2. Uptake Response Slope in Soil Biota (UB) -- UB may take any of several forms, depending on the characteristics of the chemical and the data available. UB is derived by linear regression of tissue concentration on either pollutant application rate or soil concentrations, depending on which is reported. Use of a pollutant application rate is preferable. As for plant and animal tissues (see Section 4.1.2.), two or more points are needed to derive the slope for inorganics; for synthetic organic compounds a single data pair can be used to derive a bioconcentration factor.

The highest available uptake response slope will be used to estimate the level of dietary contamination to which predators of soil biota would be subject. This fact is important to bear in mind when evaluating data for earthworms. Some studies go to lengths to distinguish between contaminant physiologically absorbed and that which is due to the gut contents (the "cast") or soil contamination of the sample. While one may suspect that the absorbed contaminant is rendered more available to the higher trophic levels, this is probably not proven or quantified. Since a predator would ingest the gut contents as well as the rest of the organism, there is no need to distinguish between absorbed and unabsorbed contaminant. Wherever possible, analyses used should be based on the whole organism.

4.7.2.3.3. Background Concentration in Soil Biota (BB) -- This value should be obtained from the same study from which UB was derived.

4.8. EXAMPLE CALCULATIONS

In this section, examples will be provided for each of the criteria calculation procedures for the different terrestrial food-chain pathways described in Sections 4.2-4.8.

One of the most important steps in criteria calculations is the selection of values for each of the parameters involved. Value selection must be based on careful literature searches and evaluations of available data. For many parts of this methodology, value selection will be a very data-intensive exercise. Since the calculations presented in this section are only for the purpose of examples, the values employed will not be based on literature searches, but will rely on a few sources of readily available information. Therefore, the results do not constitute actual recommendations for criteria. The toxic metal cadmium and the organic compound hexachlorobenzene (HCB) are used for the following examples.

4.8.1. Sludge-Soil-Plant-Human Toxicity Exposure Pathway.

4.8.1.1. PROCEDURE BASED ON CURVILINEAR ("PLATEAU") UPTAKE RESPONSE MODEL AND RELATIVE UPTAKE RESPONSE VALUES --

Step A. Determine Relative Uptake Response Values for Each Crop

Equation 4-17

$$RU_{AI} = \frac{UC_A}{UC_I}$$

where:

RU_{AI} = uptake response for crop A relative to index crop (unitless)

UC_A = linear response slope of crop A [μg/g $(kg/ha)^{-1}$]

UC_I = linear response slope of index crop [μg/g $(kg/ha)^{-1}$] in the same experiment in which UC_A was measured

Equation 4-18 (an alternative procedure to Equation 4-17)

$$RU_{AI} = \frac{A_2 - A_1}{I_2 - I_1}$$

where A_2 denotes tissue concentration of crop A in soil 2, etc.

Data Examples for Cadmium (Source: Dowdy and Larson, 1975)

	Crop A	Index Crop I
Crop type	Carrot	Lettuce
Linear response slope, UC [μg/g $(kg/ha)^{-1}$]	0.20	0.605
Tissue concentration (mean) (μg/g)	0.93	1.89
Control tissue concentration (μg/g)	0.48	0.61

Example Calculation of Equation 4-17

$$RU_{AI} = 0.20/0.605 = 0.33$$

Example Calculation of Equation 4-18

$$RU_{AI} = \frac{0.93 - 0.48}{1.89 - 0.61} = 0.35$$

In this last example, the mean of tissue concentration from three treatments was used for A_2 and I_2, and the control concentration tissue concentration was used for A_1 and I_1.

Step B. Determine Relative Uptake Response Values for Each Food Group

Data Examples for Cadmium

For the "root vegetable" food group, two crops have values of RU (Dowdy and Larson, 1975). Consumption data from Appendix 1 are used to derive a weighted average RU. Consumption data for the 25- to 30-year-old male are used.

Crop type	Carrot	Radish
Relative uptake response value, RU (unitless)	0.33	0.093
Dry-weight consumption (g DW/day)	0.55	0.021

Example Calculation for Weighted Mean (Equation not presented in text)

$$RU_{\text{root veg.}} = \frac{(0.33 \times 0.55) + (0.093 \times 0.021)}{0.55 + 0.021} = 0.32$$

Step C. Determine the Reference Tissue Concentration Increment for the Index Crop

Equation 4-20

$$RTI = \frac{RIA}{\sum_{i=1}^{n} (RU_i \times DC_i \times FC_i)}$$

where:

RTI = reference tissue concentration increment in index crop (µg/g DW)

RIA = adjusted reference intake (µg/day)

RU_i = relative uptake response for ith food group (unitless)

DC_i = daily dietary consumption of ith food group (g DW/day)

FC_i = fraction of food group assumed to originate from sludge-amended soil (unitless)

Data Examples for Cadmium

Values of RU in this example are based on very few crops (data of Dowdy and Larson, 1975). Values of DC are obtained from Table 4-2 (and Appendix 1 for legumes). DC values chosen are those for the age/sex group with highest consumption of that food group. Values of FC are those for the home garden scenario, from Table 4-12. The only legume data available in this example data set are for pea pods and pea fruit. The mean RU value will be used for dried legumes as well. The RIA value for cadmium is not based on Equation 4-14, as would normally be the case, since an Agency-approved RfD value is still pending. Instead, the FAO/WHO (1972) provisionally tolerable daily intake of 57-71 μg/day is used to derive a mean of 64 μg/day. When the Agency's RfD value for cadmium is determined it should be used to derive the RIA based on Equation 4-14. The value of BC_I in this example is 0.61 μg Cd/g and is that for lettuce from Dowdy and Larson (1975). In actuality, BC_I should be taken from the study from which RSC is derived.

Food Group	RU	DC	FC	RU x DC x FC
Potatoes	0.063	31.85	0.45	0.903
Leafy vegetables	1.0	2.78	0.60	1.668
Legume vegetables, nondried	0.008	3.38	0.60	0.016
Legume vegetables, dried	0.008	8.51	0.17	0.012
Root vegetables	0.32	2.28	0.60	0.438
Garden fruits	0.12	5.94	0.60	0.428
Grains and cereals	---	---	0	0
Peanuts	---	---	0	0
Mushrooms	---	---	0	0
TOTAL	---	---	---	3.465

Example Calculation

$$RTI = \frac{\underline{64\ \mu g\ Cd/day}}{3.465\ g/day} = 18.5\ \mu g\ Cd/g$$

Steps D and E. Sort Available Uptake Response Data for the Index Crop, and Determine Plateau Increment Values for the Index Crop

Data Examples for Cadmium

Examples are not readily available for these very data-intensive steps. Therefore a hypothetical data set for response in lettuce will be created to illustrate these steps. For each hypothetical study, it is stated whether soil pH (when the plateau was achieved) was <6.0 or ≥6.0, and whether the plateau was observed in the first year of sludge application or after >1 year. The sludge concentration (SC, in µg/g DW) of cadmium is listed, and the plateau increment value (PI, in µg/g DW), which is assumed to have been confirmed by appropriate statistical techniques and represented by a 95% confidence limit, is also listed.

Study	pH	Year	SC (µg/g DW)	PI (µg/g DW)
1	<6.0	first	200	50
2			10	5
3		multi	200	30
4			15	3
5	≥6.0	first	300	20
6		multi	300	10
7			200	12
8			15	2

Step F. Determine Reference Sludge Concentration (RSC) Not Causing Reference Tissue Concentration Increment (RTI) to be Exceeded

Four groupings of studies 1-8 are possible based on soil pH and on whether the data are from a first-year or multi-year study, as shown in Table 4-8.

Group A: Soil pH ≥6.0 or <6.0; multi-year or first-year data

All eight hypothetical studies can be included in this category, but studies with pH <6.0 and first-year response data are included only if necessary to round out the available data. Studies 6, 7 and 8 yield three P values (10, 12 and 2 μg Cd/g, respectively), all of which are well below the RTI value of 18.5 μg Cd/g. Assuming that these sludges represent a variety of sludge types and study conditions, the highest SC value, 300 μg Cd/g, can be selected as the RSC. Examination of all other uptake data (i.e., including studies not showing a plateau) must also show that no sludge with SC ≤300 μg Cd/g will cause RTI to be exceeded in a multi-year study using soil pH ≥6.0, regardless of the annual or cumulative application rate. If this were an actual value, based on expert evaluation of all the available data, this would indicate that all sludges having SC of 300 μg Cd/g or lower could be applied at unlimited cumulative rates to soils expected to remain ≥6.0 without pH control measures. Although no cumulative rate would apply, an annual Cd rate would apply since crops in the first year of sludge application could have a higher cadmium content (see Table 4-8). The annual Cd rate would have to be less than the highest rates employed in study 5, for example, since RTI was exceeded at the plateau. The annual rate is determined based on further evaluation of rates used in studies 5-8, or based on the procedure using the linear model.

Group B: Soil pH <6.0 only; multi-year or first-year data

Studies 1-4 are potentially included in this group; studies 1 and 2 are included only if needed to augment the available data. Studies 3 and 4 indicate that sludges with SC of 200 μg Cd/g may cause RTI to be exceeded, but those with SC of ≤15 μg Cd/g will not. Studies 1 and 2 strengthen this conclusion; therefore, RSC is set at 15 μg Cd/g. If an actual value, this would mean that sludges not exceeding this cadmium concentration could be applied in unlimited cumulative amounts to all soils regardless of pH. An annual application rate would still apply, however.

Group C: Soil pH ≥ 6.0 or <6.0; first-year only

Studies 1, 2 and 5 potentially fit this group. Study 5 shows only that one sludge with SC of 300 µg Cd/g will just cause RTI (18.5 µg Cd/g) to be exceeded. Therefore studies 1 and 2 must be included as well, and they indicate that an SC of 200 µg Cd/g caused RTI to be exceeded in the first year, but that an SC of 10 µg Cd/g did not. Based on these observations an RSC of 10 µg Cd/g is determined. If an actual value, sludges not exceeding this concentration could be applied with no annual or cumulative rate limit to soils expected to remain at pH ≥ 6.0 without liming.

Group D: Soil pH <6.0 only; first-year data only

Only studies 1 and 2 may be considered. These studies show only that an SC of 200 µg Cd/g caused RTI to be substantially exceeded and that an SC of 10 µg Cd/g stayed well under the RTI. RSC would be set at 10 µg Cd/g if the data were judged to be reliable. If an actual value, sludges not exceeding RSC = 10 µg Cd/g could be applied to all soils regardless of pH and without annual or cumulative rate limits.

Step G. Check the Reference Sludge Concentration (RSC) by Substituting Other Crops for the Index Crop

Equation 4-21

$$RTI_S = RTI_I \times RU_{SI}$$

where:

RTI_S = reference tissue concentration increment for substitute crop (µg/g DW)

RTI_I = reference tissue concentration increment for index crop (µg/g DW)

RU_{SI} = uptake response in substitute crop relative to index crop (unitless)

Data Examples for Cadmium

Carrot will be chosen as a substitute crop. All data are as given above.

Example Calculation

$$RTI_S = 18.5\ \mu g\ Cd/g \times 0.33 = 6.1\ \mu g\ Cd/g$$

Steps D-F are then repeated using plateau data and other response data for the substitute crop. RSC is adjusted downward if necessary.

4.8.1.2. PROCEDURE BASED ON LINEAR UPTAKE RESPONSE MODEL AND RELATIVE UPTAKE RESPONSE VALUES --

Steps A-C

Steps A-C are identical to Steps A-C using the curvilinear uptake response model. For cadmium, an RTI of 18.5 μg Cd/g is derived.

Steps D-E

Steps D-E utilize a sorting procedure identical to that described for the curvilinear approach, except that values of the uptake response slope (UC) for the index crop are sorted, rather than plateau values (P).

Step F. Determine Reference Application Rate of the Pollutant (RP)

Equation 4-23

$$RP = RTI/UC_I$$

where:

RP = reference application rate of pollutant (kg/ha)

RTI = reference tissue concentration increment of index crop (μg/g DW)

UC_I = uptake response slope of index crop [$\mu g/g\ (kg/ha)_{-1}$]

Data Examples for Cadmium

Index crop	RTI	UC_I
Lettuce	18.5	0.605

Example Calculation

$$RP = (18.5\ \mu g\ Cd/g)/[0.605\ \mu g\ Cd/g\ (kg\ Cd/ha)^{-1}]$$

$$= 30.6\ kg\ Cd/ha$$

Step G. Check the Reference Application Rate of the Pollutant (RP) by Substituting Other Crops for the Index Crop

Data Examples for Cadmium

RTI_S is derived using Equation 4-21, as shown previously.

Substitute Crop	RTI_S	UC_S
Carrot	6.1	0.20

Example Calculation (see Equation 4-23, above)

$$RP_S = (6.1\ \mu g\ Cd/g)/[0.20\ \mu g\ Cd/g\ (kg\ Cd/ha)^{-1}]$$
$$= 30.5\ kg\ Cd/ha$$

RP_S is in virtual agreement with RP (except for rounding error) because both of the UC values used were also used to derive values of RU and RTC. This will not always be the case, however, since values of UC from different sorting groups established in Steps D and E will be used to calculate various values of RP, as shown in Table 4-10.

Step H. Adjust the Reference Application Rate of the Pollutant (RP) for Phytotoxic Effects

A maximum pollutant application rate RPM_i (kg/ha) based on phytotoxicity is determined for each crop group used to calculate RTC.

Equation 4-24

$$RPM_i = (TL_i - BC_i)/(RU_i \times UC_I)$$

where:

TL_i = maximum tissue concentration for crop category i, above which crop production is virtually eliminated by phytotoxicity (μg/g DW)

BC_i = background concentration for crop category i (μg/g DW)

RU_i = relative uptake response value for crop category i (unitless)

UC_I = uptake response slope for index crop, used to determine the RP value being adjusted [μg/g DW $(kg/ha)^{-1}$]

Data Examples for Cadmium

Data for RU, DC and FC (which will be needed below) are those used above to determine RTI. Data for TL and BC are matched values (i.e., from the same study) and are selected or estimated from U.S. EPA (1985e).

Crop	RU	TL	BC	DC	FC	RPM_i	Σ (subscript)
Potatoes	0.063	NA	NA	31.85	0.45	NC	0.903 (k)
Leafy vegetables	1.0	668	12.2	2.78	0.60	1084	1.668 (k)
Legume vegetables, nondried	0.008	28.2	5.7	3.38	0.60	4649	0.016 (k)
Legume vegetables, dried	0.008	28.2	5.7	3.38	0.17	4649	0.012 (k)
Root vegetables	0.32	29.8	2.4	2.28	0.60	142	37.5 (j)
Garden fruits	0.12	15	0.1	5.94	0.60	205	53.1 (j)

RPM_i for each crop group is compared with RP. If RPM_i <RP for any crop, then RP must be adjusted. In this case RPM_i >RP (31.6 kg Cd/ha) for all crops, indicating that phytotoxicity will not occur in any crop before RTC is reached in the reference crop.

To demonstrate what should be done if RPM_i <RP, the value of RIA can be increased by a factor of 10 to give an RP value of 306 kg Cd/ha (see Equations 4-20 and 4-23, above). RPM_i is now exceeded for root vegetables and garden fruits. These crops are assigned subscript j in Equation 4-25; the remaining crops are assigned subscript k.

Equation 4-25

$$RTI = \frac{RIA - \sum_{j=1}^{n} [(TL_j - BC_j) \times DC_j \times FC_j]}{\sum_{k=1}^{n} (RU_k \times DC_k \times FC_k)} \qquad (4\text{-}25)$$

where all symbols are as defined above.

Example Calculation

The bracketed quantities in Equation 4-25 are calculated in the above table for each crop group, as shown under the summation symbol. The appropriate subscript for each group is shown in parentheses.

$$RTI = \frac{[640 - (37.5 + 53.1)]\ \mu g\ Cd/day}{(0.903 + 1.668 + 0.016 + 0.012)\ g/day} = 211\ \mu g\ Cd/g$$

RP is now calculated using Equation 4-23, as shown previously.

$$RP = (211\ \mu g\ Cd/g)/[0.605\ \mu g\ Cd/g\ (kg\ Cd/ha)^{-1}]$$
$$= 349\ kg\ Cd/ha$$

The adjusted RP is somewhat higher (349 >306) because the Cd concentrations in root vegetables and garden fruits have been held at their phytotoxic tissue concentrations, and have not been allowed to exceed them.

4.8.1.3. PROCEDURE BASED ON LINEAR UPTAKE RESPONSE MODEL WITHOUT USING RELATIVE UPTAKE RESPONSE VALUES --

Steps A & B. Sort Available Uptake Response Data for All Food Crops, and Determine Uptake Response Slopes for Each Food Group

Data Examples for Cadmium

Sorting of studies according to soil pH and whether a first-year or multi-year study is done as shown previously. Using the data of Dowdy and Larson (1975) (pH $\geq$6.0; first-year response data), response slopes for two crops are used to derive a weighted mean response slope for the "root vegetable" food group. Consumption data are those for the 25- to 30-year-old male, from Appendix 1.

Crop type	Carrot	Radish
Linear uptake response slope, UC [$\mu g/g\ (kg/ha)^{-1}$]	0.20	0.056
Dry-weight consumption (g DW/day)	0.55	0.021

Example Calculation of Weighted Mean (equation not presented in text)

$$UC_{root\ veg.} = \frac{(0.20 \times 0.55) + (0.056 \times 0.021)}{0.55 + 0.021}$$
$$= 0.19\ \mu g\ Cd/g\ (kg\ Cd/ha)^{-1}$$

Step C. Determine Reference Application Rate of Pollutant (RP)

Equation 4-26

$$RP = \frac{RIA}{\sum_{i=1}^{n} (UC_i \times DC_i \times FC_i)}$$

where:

RP = reference application rate of pollutant (kg/ha)

RIA = adjusted reference intake (μg/day)

UC_i = uptake response slope for ith food group [μg/g DW $(kg/ha)^{-1}$]

DC_i = daily dietary consumption of ith food group (g DW/day)

FC_i = fraction of food group assumed to originate from sludge-amended soil (unitless)

Data Examples for Cadmium

The UC data set from Dowdy and Larson (1975) is used to illustrate this step. Values of DC, FC and RIA (64 μg Cd/g) are the same as shown previously.

Food Group	UC	DC	FC	UC x DC x FC
Potatoes	0.038	31.85	0.45	0.545
Leafy vegetables	0.605	2.78	0.60	1.009
Legume vegetables, nondried	0.0053	3.38	0.60	0.011
Legume vegetables, dried	0.0053	8.51	0.17	0.008
Root vegetables	0.19	2.28	0.60	0.260
Garden fruits	0.073	5.94	0.60	0.260
TOTAL	---	---	---	2.093

Example Calculation of Equation 4-26

$$RP = \frac{64 \text{ μg Cd/day}}{2.093 \text{ μg/day } (kg/ha)^{-1}} = 30.6 \text{ kg/ha}$$

Step D. Adjust the Reference Application Rate of the Pollutant (RP) for Phytotoxic Effects

The procedure for adjusting RP (using Equation 4-27) is nearly identical to that shown previously using Equation 4-25, and will not be repeated here.

This value of RP (30.6 kg Cd/ha) is in agreement with that calculated using the previous procedure, because the same data set was used. Ordinarily, UC values for various crops would be obtained from different studies when this procedure is used.

The interpretation of RP depends on the data sort (Step A of this procedure) from which the UC values were taken, as explained in Table 4-10.

4.8.2. Sludge-Human Toxicity (Soil Ingestion) Exposure Pathway.

4.8.2.1. CALCULATION OF ADJUSTED REFERENCE INTAKE (RIA) -- The organic compound hexachlorobenzene (HCB) will be used as an example. Since HCB is a carcinogen, Equation 4-16 is used.

Equation 4-16

$$RIA = \left[\left(\frac{RL \times bw}{q_1^* \times RE}\right) - TBI\right] \times 10^3$$

where:

RIA = adjusted reference intake (μg/day)

q_1^* = human cancer potency [(mg/kg/day)$^{-1}$]

RL = risk level (unitless) (10^{-5}, 10^{-6}, etc.)

bw = human body weight (kg)

RE = relative effectiveness of ingestion exposure (unitless)

TBI = total background intake rate of pollutant (mg/day); from all other sources of exposure

10^3 = conversion factor (μg/mg)

Data Examples for HCB

The human cancer potency (q_1^*) for HCB has been determined by the U.S. EPA to be 1.7 (mg/kg/day)$^{-1}$ (U.S. EPA, 1985c). RL, bw and RE are set at

10^{-6}, 10 kg (for a 1-year-old child) and 1.0 for this example. A current TBI of HCB from all other sources has not been determined for 1986; for illustrative purposes a value of 0 is used here.

Example Calculation of Equation 4-16

$$\text{RIA} = \frac{10^{-6} \times 10 \text{ kg}}{1.7 \text{ (mg/kg/day)}^{-1} \times 1.0} - 0 \times 10^{3}$$

$$= 0.0059 \ \mu\text{g/day for a 10-kg child}$$

4.8.2.2. CALCULATION OF REFERENCE SOIL CONCENTRATION (RLC) --

Equation 4-28

$$\text{RLC} = \text{RIA}/(I_s \times \text{DA}) \qquad (4\text{-}28)$$

where:

RLC = reference soil concentration of pollutant (μg/g DW)
RIA = adjusted reference intake (μg/day)
I_s = soil ingestion rate (g DW/day)
DA = exposure duration adjustment (unitless)

Data Examples for HCB

RIA is 0.0059 μg/day for a 10-kg child, as derived above. I_s and DA are 0.5 g/day and 0.07, as explained in Section 4.3.3.

Example Calculation of Equation 4-28

$$\text{RLC} = (0.0059 \ \mu\text{g HCB/day})/(0.5 \text{ g/day} \times 0.07)$$

$$= 0.17 \ \mu\text{g HCB/g soil}$$

4.8.2.3. CALCULATION OF REFERENCE SLUDGE CONCENTRATION (RSC) -- If sludge is not soil-incorporated, and assuming that immediate potential exists for exposure of children, then RSC = RLC = 0.17 μg HCB/g.

4.8.2.4. CALCULATION OF REFERENCE ANNUAL APPLICATION RATE OF POLLUTANT (RP_a) -- Assuming that sludge will be soil-incorporated and that annual applications will be made, Equation 4-13 is used to calculate RP_a from RLC.

Equation 4-13

$$RP_a = RLC \times MS \times 10^{-3} \times e^{kT} [1 + De^{-k} + D^2e^{-2k} + \ldots + D^{n-1}e^{(1-n)k}]^{-1}$$

where:

RP_a = reference annual application rate of pollutant (kg/ha)
RLC = reference soil concentration of pollutant (µg/g DW)
MS = 2×10^3 t/ha = assumed mass of soil in upper 15 cm
10^{-3} = conversion factor (kg/g)
e = base of natural logarithms, 2.718 (unitless)
k = loss rate constant (years^{-1})
T = waiting (or land-use conversion) period (years)
D = $(MS-AR_a)/MS$
AR_a = annual application rate (t DW/ha)

Data Examples for HCB

RLC is 0.17 µg HCB/g soil, as determined above. A k value of 0.165 years^{-1} (corresponding to a soil half-life of 4.2 years; U.S. EPA, 1985f) is used. No waiting period will be assumed (T = 0). AR_a is 5 Mg DW/ha and therefore D = 0.9975 ≃ 1.0. The number of annual applications is assumed to be infinite, and therefore n = 5.6/k = 5.6/0.165 = 34 will be used, as explained in Section 4.1.1.3.2.

$$RP_a = 0.17 \text{ µg HCB/g} \times 2000 \text{ t/ha} \times 10^{-3} \text{ kg/g} \times e^0 \times [1 + 1\ e^{-0.165} + 1^2\ e^{-2(0.165)} + \ldots + 1^{33}\ e^{-33(0.165)}]^{-1}$$

$$= 0.17 \text{ µg HCB/g} \times 2000 \text{ t/ha} \times 10^{-3} \text{ kg/g} \times 1 \times [6.6]^{-1}$$

$$= 0.052 \text{ kg HCB/ha}$$

4.8.3. Exposure Pathways for Herbivorous Animals for Human Consumption.

4.8.3.1. CALCULATION OF REFERENCE FEED CONCENTRATION (RFC) -- The toxic metal cadmium will be used as an example. Equation 4-30 is used to calculate RFC. Calculations for the "uptake" pathway (sludge-soil-plant-animal-human toxicity) and "adherence" pathway [sludge-animal(direct ingestion)-human toxicity] are presented.

Equation 4-30

$$RFC = \frac{RIA}{\sum (UA_i \times DA_i \times FA_i)}$$

where:

RFC = reference feed concentration of pollutant (μg/g DW)

RIA = adjusted reference intake of pollutant in humans (μg/day)

UA_i = uptake response slope of pollutant in the ith animal tissue [μg/g tissue DW $(\mu g/g \text{ feed DW})^{-1}$]

DA_i = daily dietary consumption of ith animal tissue food group (g DW/day)

FA_i = fraction of food group assumed to be derived from sludge-amended soil or feedstuffs

Data Examples for Cadmium

The RIA of 64 μg/day was explained previously. Values of UA for various animal tissues are taken from U.S. EPA (1985e) (converted from wet to dry weight basis). The value listed for "beef liver" is actually from sheep kidney; it is the highest UA value for an organ meat, since the beef liver consumption data are assumed here to represent any organ meat. No data were available for pork; an average of the values for beef and lamb was used. Data were also unavailable for eggs and dairy products. In this example they are assumed to be similar to poultry muscle and beef muscle, respectively. The DA values are derived from Table 4-2. They include fat, since the UA values are on a dry weight (including fat) basis. The FA values are from Table 4-18; they differ for the uptake and adherence pathways.

Animal Tissue Group	UA	DA	FA Uptake	FA Adherence	UA x DA x FA (when FA≠0)
Beef	0.003	56.2	0.44	0.44	0.074
Beef liver	9.9	1.22	0.44	0.44	5.31
Lamb	0.005	0.37	0.44	0.44	0.0008
Pork	0.004	32.7	0.44	0	0.058
Poultry	0.08	11.0	0.34	0	0.30
Dairy	0.003	83.1	0.40	0.40	0.10
Eggs	0.08	11.5	0.48	0	0.44
TOTAL	---	---	---	---	6.29

Example Calculation of Equation 4-30

For the uptake pathway:

$$\text{RFC} = \frac{64\ \mu\text{g/day}}{6.29\ \text{g/day}} = 10.2\ \mu\text{g Cd/g}$$

For the adherence pathway:

$$\text{RFC} = \frac{64\ \mu\text{g/day}}{[6.29 - (0.058 + 0.30 + 0.44)]\ \text{g/day}} = 11.7\ \mu\text{g Cd/g}$$

4.8.3.2. CALCULATE A REFERENCE APPLICATION RATE FOR THE UPTAKE PATHWAY

Equation 4-31

$$RP_c = RFC/UC$$

where:

RP_c = reference cumulative application rate of pollutant (kg/ha)
RFC = reference feed concentration of pollutant (µg/g DW)
UC = linear response slope of forage crop [µg/g crop DW $(\text{kg/ha})^{-1}$]

Data Examples for Cadmium

RFC for the uptake pathway is 10.2 µg Cd/g as calculated above. A UC value of 0.14 µg Cd/g $(\text{kg Cd/ha})^{-1}$ based on corn silage will be used (U.S. EPA, 1985e).

Example Calculation of Equation 4-31

$$RP_c = (10.2\ \mu\text{g Cd/g})/(0.14\ \mu\text{g Cd/g}[\text{kg Cd/ha}]^{-1})$$
$$= 72.9\ \text{kg Cd/ha}$$

4.8.3.3. **CALCULATE A REFERENCE APPLICATION RATE FOR THE ADHERENCE PATHWAY, ASSUMING SOIL INCORPORATION OF SLUDGE** -- A reference soil concentration of pollutant RLC (μg/g DW) is first calculated using Equation 4-33.

Equation 4-33

$$RLC = (RFC/FL) + BS$$

where:

RFC = reference feed concentration of pollutant (μg/g DW)
FL = fraction of diet that is adhering soil (g soil DW/g diet DW)
BS = background soil concentration of pollutant (μg/g DW)

Data Examples for Cadmium

RFC for the adherence pathway is 11.7 μg Cd/g, as calculated previously. FL is 0.10, as explained in Section 4.4.3.3. BS is 0.2 μg Cd/g (U.S. EPA, 1985e).

Example Calculation for Equation 4-33

$$RLC = [(11.7\ \mu g\ Cd/g)/0.10] + 0.2\ \mu g\ Cd/g = 117.2\ \mu g\ Cd/g$$

A reference application rate is next calculated using Equation 4-3.

Equation 4-3

$$RP = (RLC-BS) \times MS \times 10^{-3}$$

where:

RP = reference application rate of pollutant (kg/ha)
RLC = reference soil concentration of pollutant (μg/g DW)
BS = background concentration of pollutant in soil (μg/g DW)
MS = 2×10^3 t/ha = assumed mass of soil in upper 15 cm
10^{-3} = conversion factor (kg/g)

Data Examples for Cadmium

RLC is 117.2 μg Cd/g, as calculated above, and BS is 0.2 μg Cd/g.

Example Calculation of Equation 4-3

$$RP = (117.2\ \mu g\ Cd/g - 0.2\ \mu g\ Cd/g) \times 2000\ t/ha \times 10^{-3}\ kg/g$$

$$= 234\ kg\ Cd/ha$$

4.8.3.4. CALCULATE A REFERENCE SLUDGE CONCENTRATION FOR THE ADHERENCE PATHWAY, ASSUMING SLUDGE IS NOT SOIL-INCORPORATED --

Equation 4-34

$$RSC = \frac{RFC}{FS}$$

where:

RSC = reference sludge concentration (μg/g DW)
RFC = reference feed concentration (μg/g DW)
FS = fraction of animal diet which is sludge (unitless)

Data Examples for Cadmium

RFC is 11.7 μg Cd/g as calculated above. FS is 0.08 if a 30-day waiting period before grazing or harvesting is assumed (see Section 4.4.3.3.).

Example Calculation of Equation 4-34

$$RSC = (11.7 \ \mu g \ Cd/g)/0.08 = 146 \ \mu g \ Cd/g$$

4.8.4. Exposure Pathways for Toxicity to Herbivorous Animals.

4.8.4.1. CALCULATE A REFERENCE FEED CONCENTRATION --For the uptake pathway (sludge-soil-plant-animal toxicity), a wider variety of herbivores may be affected than for the adherence pathway (sludge-animal toxicity [direct ingestion]), which affects only grazing animals. An example will be shown for the uptake pathway.

Equation 4-35

$$RFC = TA - BC$$

where:

RFC = reference feed concentration (μg/g DW)
TA = threshold feed concentration (μg/g DW)
BC = background concentration in feed crop (μg/g DW)

Data Examples for Cadmium

TA is calculated as a geometric mean of levels just causing and not causing an adverse effect, as described in Section 4.1.3. In a 48-week study with chickens, feed concentrations of 3 and 12 μg Cd/g (added as

$CdSO_4$) showed no adverse effect and decreased eggshell thickness, respectively (U.S. EPA, 1985e). A geometric mean of $(3 \times 12)^{1/2} = 6$ µg Cd/g is calculated. A BC of 0.1 µg Cd/g is typical of corn grain.

Example Calculation of Equation 4-35

$$RFC = 6 \text{ µg Cd/g} - 0.1 \text{ µg Cd/g} = 5.9 \text{ µg Cd/g}$$

4.8.4.2. CALCULATE A REFERENCE APPLICATION RATE OR REFERENCE SLUDGE CONCENTRATION -- Criteria derivation procedures for the herbivorous animal toxicity pathways utilize Equations 4-31 to 4-34, as have just been demonstrated.

4.8.5. Sludge-Soil-Plant Toxicity Exposure Pathway.

No calculations are required for this pathway, except in some cases to convert RLC to RP, as has already been demonstrated.

4.8.6. Exposure Pathways for Toxicity to Soil Biota and Their Predators.

4.8.6.1. SLUDGE-SOIL-SOIL BIOTA TOXICITY EXPOSURE PATHWAY -- This pathway also does not require calculations, except in some cases conversion of RLC to RP, as has already been demonstrated.

4.8.6.2. SLUDGE-SOIL-SOIL BIOTA-PREDATOR TOXICITY EXPOSURE PATHWAY -- Calculations use either Equation 4-37 or 4-38, depending on the units associated with the uptake response slope in soil biota, UB. In this example, Equation 4-38 is used.

Equation 4-38

$$RLC = \frac{TA - BB}{UB} + BS$$

where:

RLC = reference soil concentration of pollutant (µg/g DW)
TA = threshold feed concentration (µg/g DW)
BB = background concentration in soil biota (µg/g DW)
UB = uptake response slope in soil biota [µg/g(µg/g)$^{-1}$]
BS = background soil concentration of pollutant (µg/g DW)

Data Examples for Cadmium

TA is 6 μg Cd/g, as derived previously based on effects in chickens. BB and UB are 4.8 μg Cd/g and 13.7 μg Cd/g $(\mu g\ Cd/g)^{-1}$, respectively, based on observations in earthworms (U.S. EPA, 1985e). BS is 0.2 μg Cd/g, as given previously.

Calculation Examples for Cadmium

$$\text{RLC} = \frac{6\ \mu g\ Cd/g - 4.8\ \mu g\ Cd/g}{13.7\ \mu g\ Cd/g\ (\mu g\ Cd/g)^{-1}} + 0.2\ \mu g\ Cd/g$$

$$= 0.088 + 0.2\ \mu g\ Cd/g$$

$$= 0.29\ \mu g\ Cd/g$$

RLC is then converted to an application rate, as previously demonstrated.

This last example demonstrates the need for thorough data analysis and peer review of calculated results. The TA value of 6 μg Cd/g is based on effects of $CdSO_4$ on chickens. This value is only slightly higher than the background concentration of cadmium in earthworms (4.8 μg Cd/g) in the study giving the highest UB. [Other studies list background concentrations of as high as 17 μg Cd/g in earthworms (U.S. EPA, 1985e).] The resulting calculation suggests that an increase of less than one-half of the mean soil background concentration would cause toxicity in birds consuming earthworms. This unlikely result suggests either that chickens are more sensitive to cadmium than birds that feed on earthworms, or that $CdSO_4$ is an inappropriate surrogate for cadmium in earthworms. Therefore, thorough evaluation of all available data on species' sensitivities to various forms of cadmium is needed to select the most appropriate values for criteria derivation.

5. EXPOSURE AND ASSESSMENT OF HEALTH EFFECTS FROM INHALED PARTICULATES

5.1. INHALATION OF PARTICULATES

The inhalation of particulates generated by application and wind erosion is a potentially significant source of human exposure to sludge contaminants. A rough quantitative analysis was performed for cadmium in this pathway to estimate exposures by inhalation. It was assumed that exposures from wind erosion would be far less than exposures during application, and that injection of liquid sludge into the surface soil would not generate any particulates. Therefore, particulate emissions from spreader application and subsequent tilling of dewatered sludge were examined. The analysis was done using the emission factor for agricultural tilling (use of a disc, land plane or sweep plow) presented in AP-42 (U.S. EPA, 1983a).

5.2. DUST EMISSION FACTOR

The quantity of dust emission from agricultural tilling of sludge per hectare of land tilled may be estimated using the following empirical expressions (U.S. EPA, 1983a).

$$E = k\ (5.38)\ (s)^{0.6} \qquad (5\text{-}1)$$

where:

E = emission factor (kg/ha)
s = silt content of soil (%)
k = particle size multiplier (dimensionless)

The particle size multiplier (k) in the equation varies with aerodynamic particle size range as follows:

Aerodynamic Particle Size Multiplier
(k)

Total Particulate	<30 μm	<15 μm	<10 μm	<5 μm	<2.5 μm
1.0	0.33	0.25	0.21	0.15	0.10

A number of assumptions have been made that enable the use of this expression for agricultural tilling of sludge. These assumptions follow:

1. The sludge and soil particulates are emitted in proportion to their concentration in the tilled zone (the top 15 cm).
2. The sludge and soil are well mixed.
3. The silt content of the soil is 20% ($s = 0.2$).
4. The size of the particulates inhaled and ingested is <30 µm ($k = 0.33$).

Therefore,

$$E = (0.33)\ (5.38)\ (0.2)^{0.6} = 0.6759 \text{ kg/ha}$$

These are all conservative assumptions, which will tend to overestimate the sludge particulate emissions generated from tilling. Therefore, the results provide a conservative indication of the relative significance of sludge particulate emissions.

5.3. DUST EMISSION RATE AND AIR CONCENTRATION DETERMINATION

As shown in Section 5.2., the emission factor of tilling sludge-treated soils can be calculated to be 0.6759 kg/ha based on the assumptions made. An emission rate (EM) in g/sec can be calculated using this emission factor as follows:

$$EM = E \times (1000 \text{ g/kg}) \times A \times (0.405 \text{ ha/ac}) \times (8 \text{ hr}/28{,}000 \text{ sec}) \qquad (5\text{-}2)$$

where:

EM = emission rate (g/sec)
E = emission factor (kg/ha)
A = acres tilled/8-hour day

Assuming 100 acres (ac) of land are tilled in 8 hours, the dust emission rate is 0.95 g/sec. This dust emission rate is obtained from the following expression:

$$EM = (0.6759 \text{ kg/ha})(1000 \text{ g/kg})(100 \text{ ac}/8 \text{ hr})(0.405 \text{ ha/ac})(8 \text{ hr}/28{,}800 \text{ sec})$$
$$= 0.95 \text{ g/sec}$$

The height is assumed to be 0.5 m with the initial horizontal and vertical dispersion parameters set at 0.5. The tractor driver is assumed to be between 1 and 2 m from the tiller at a receptor height of 2.44 m. A Gaussian Integrated PUFF model, INPUFF, is used to estimate the concentrations of dust to which the driver is exposed. INPUFF (Petersen et al., 1984) is based on Gaussian puff assumptions including a vertically uniform wind direction field and no pollutant removal or chemical reactions.

In Gaussian-puff algorithms, source emissions are treated as a series of puffs emitted into the atmosphere. Constant conditions of wind and atmospheric stability are assumed during a time interval. The diffusion parameters are functions of travel time.

During each time step, the puff centers are determined by the trajectory and the inpuff distributions are assumed to be Gaussian. Thus, each puff has a center and a volume that are determined separately by the mean wind, atmospheric stability and travel time.

INPUFF was performed across a range of windspeeds under atmospheric stabilities D and B. The table below lists characteristics of the meteorological conditions defining the turbulence types (stabilities).

Surface Wind-Speed (m/sec)	Daytime Isolation		
	Strong	Moderate	Slight
<2	A	A-B	B
2	A-B	B	C
3	B	B-C	C
6	C	C-D	D
6>	C	D	D

A = Extremely unstable
B = Moderately unstable
C = Slightly unstable
D = Neutral (also applicable to heavy overcast)

The INPUFF modeling results range between 2.4×10^{-2} and 2.6×10^{-6} g/m^3 for stability D and between 3.3×10^{-2} and 1.5×10^{-3} g/m^3 for stability B.

The 1- to 2-meter distance corresponds to extremely short travel times for the puff modeling. Also, the tractor driver is a fixed distance from the emission source but this fixed framework is moving with the wind field. The model is not capable of properly accounting for this relationship. The results are quite rough, but of all the atmospheric models currently available, INPUFF is considered to be the most appropriate.

5.4. EXAMPLE CALCULATION

Using the amount of 3.3×10^{-2} g/m^3 as worst case, the following calculations were made for cadmium assuming: 1) 8-hour daily exposure; 2) no controls for dust exposure (no personal protection or dust suppression); and 3) a total of 20 kg/ha of cumulative cadmium added, the amount currently allowed to protect the human food chain. The calculations and results are shown in Table 5-1. The cadmium concentration in the worker's breathing zone resulting from the application of sludge was determined to be 330 ng/m^3. This value is 0.17% of the Occupational Safety and Health Administration (OSHA) Standard for cadmium dust, and 0.83% of the more conservative National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit of 0.04 mg/m^3 (CDC, 1983). Therefore, the above analysis suggests that the public health impact of the inhalation of cadmium in airborne particulates generated from land application of municipal sewage sludge may be relatively insignificant. In the case of residential use, the time spent tilling the soil and generating particulates that could be inhaled is less than that found in the agricultural setting.

TABLE 5-1

Particulate Exposure to Cadmium from Land Application of Dewatered Sewage Sludge

---

Exposure (ng/day) = Particulate concentration of <30 μm particles x pollutant concentration in soil

Input Data

Pathway specific: Particulate concentration = 3.3×10^{-2} g/m^3 = 33×10^6 ng/m^3

Pollutant specific: Pollutant added to soil = 20 kg Cd/ha
Mass in top 15 cm = 2×10^6 kg soil/ha

$$\text{Pollutant concentration in soil} = \frac{20 \text{ kg Cd/ha}}{2\times10^6 \text{ kg soil/ha}}$$

$$= 10\times10^{-6} \text{ kg Cd/kg soil}$$

$$= 10 \text{ mg Cd/kg soil}$$

$$\text{Exposure} = \frac{33\times10^6 \text{ ng soil}}{\text{m}^3} \times \frac{10 \text{ mg Cd}}{\text{kg soil}} = 330 \text{ ng/m}^3$$

OSHA Standard = 0.2 mg/m^3 8-hour time-weighted average (TWA)

$$330 \text{ ng/m}^3 \times \frac{1}{0.2 \text{ mg/m}^3 \times 10^6 \text{ ng/mg}} \times 100 = 0.17\%$$

Occupational Safety and Health Administration (OSHA)

NIOSH Exposure Limit = 0.04 mg/m^3

$$330 \text{ ng/m}^3 \times \frac{1}{0.04 \text{ mg/m}^3 \times 10^6 \text{ ng/mg}} \times 100 = 0.83\%$$

National Institute for Occupational Safety and Health (NIOSH)

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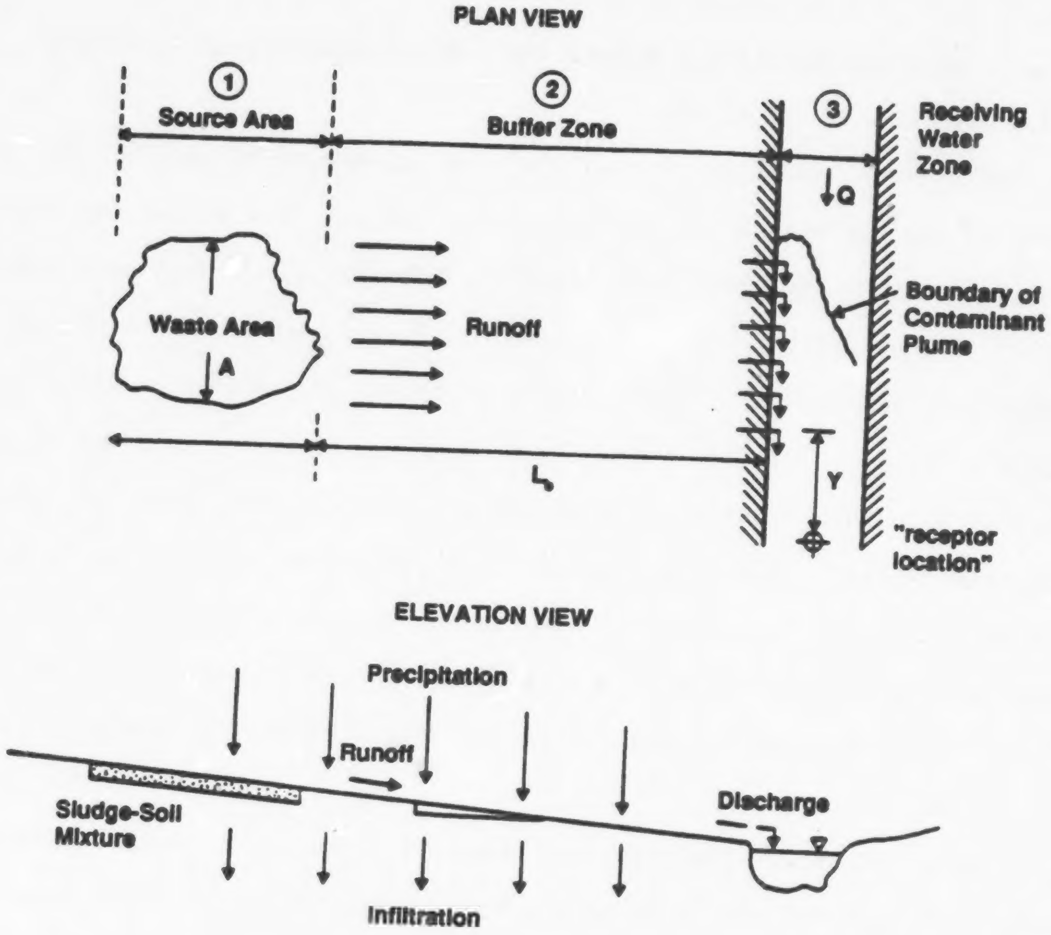
6. CRITERIA CALCULATION METHODS FOR SURFACE RUNOFF EXPOSURE PATHWAY

6.1. OVERVIEW OF THE METHOD

The surface runoff portion of the risk assessment methodology has been designed for application on a site-specific basis. This allows the regulatory program to consider site-specific characteristics that may greatly affect overall risk levels. Site-specific approaches can be difficult to implement, proportional to the level of detail to which the analysis is taken. The more specific the analysis, the more data are required to support it and, therefore, the greater the difficulty. Thus, a tiered approach has been devised. The first tier is conservative but requires little data. If applicants are not satisfied with the results of this level of inquiry, they have the option to go to a more detailed level of analysis at greater effort. The tradeoff between effort and degree of restrictiveness is left to the applicant.

Figure 6-1 shows the plan and elevation view of a sludge management area. The system consists of an application area within a larger watershed area. There may be an intervening buffer zone between the application area and the receiving water body. The receiving water body might be a stream, lake or estuary. Important processes are also indicated in the figure.

The overall scheme for evaluating concentrations of pollutants in surface waters that are due to surface runoff from sludge management areas (SMAs) is shown in Figures 6-2a and 6-2b. Figure 6-2a shows the flow chart for determining long-term average concentrations in streams, lakes and estuaries; figure 6-2b shows the flow chart for determining concentrations in receiving waters resulting from single storm events. The computations have been separated into these two problem types to evaluate both chronic and acute exposures. This methodology is designed to address toxic


PLAN VIEW
①
Source Area
②
Buffer Zone
③
Receiving Water Zone
Q
Waste Area
A
Runoff
Boundary of Contaminant Plume
L
Y
"receptor location"
ELEVATION VIEW
Precipitation
Runoff
Sludge-Soil Mixture
Discharge
Infiltration

Zone	Important Processes
1.	Precipitation, Infiltration, Runoff Erosion Contaminant Speciation, Pathways
2.	Precipitation, Infiltration, Runoff Erosion Sedimentation Dilution/Infiltration of Contaminant
3.	Initial Mixing Advection/Dispersion Settling

FIGURE 6-1

Schematic of Surface Runoff and Erosion from a Sludge Land Application Area As Addressed by the Methodology

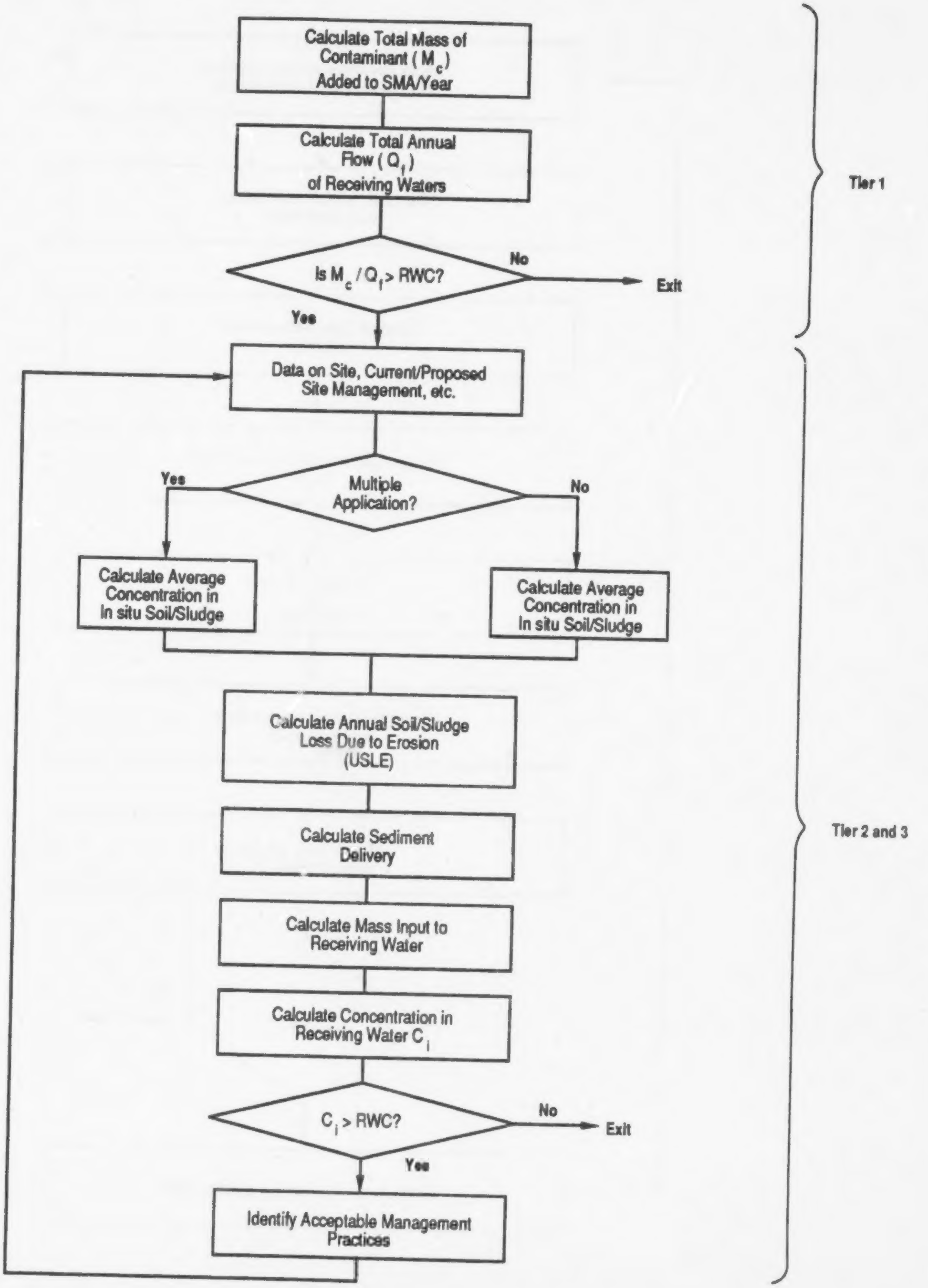

Calculate Total Mass of Contaminant (M_c) Added to SMA/Year
Calculate Total Annual Flow (Q_f) of Receiving Waters
Is $M_c / Q_f >$ RWC?
No
Exit
Yes
Tier 1
Data on Site, Current/Proposed Site Management, etc.
Multiple Application?
Yes
No
Calculate Average Concentration in In situ Soil/Sludge
Calculate Average Concentration in In situ Soil/Sludge
Calculate Annual Soil/Sludge Loss Due to Erosion (USLE)
Calculate Sediment Delivery
Calculate Mass Input to Receiving Water
Calculate Concentration in Receiving Water C_i
$C_i >$ RWC?
No
Exit
Yes
Identify Acceptable Management Practices
Tier 2 and 3

FIGURE 6-2a

Flow Chart for Estimating Long-Term Average Concentrations As Addressed by the Methodology

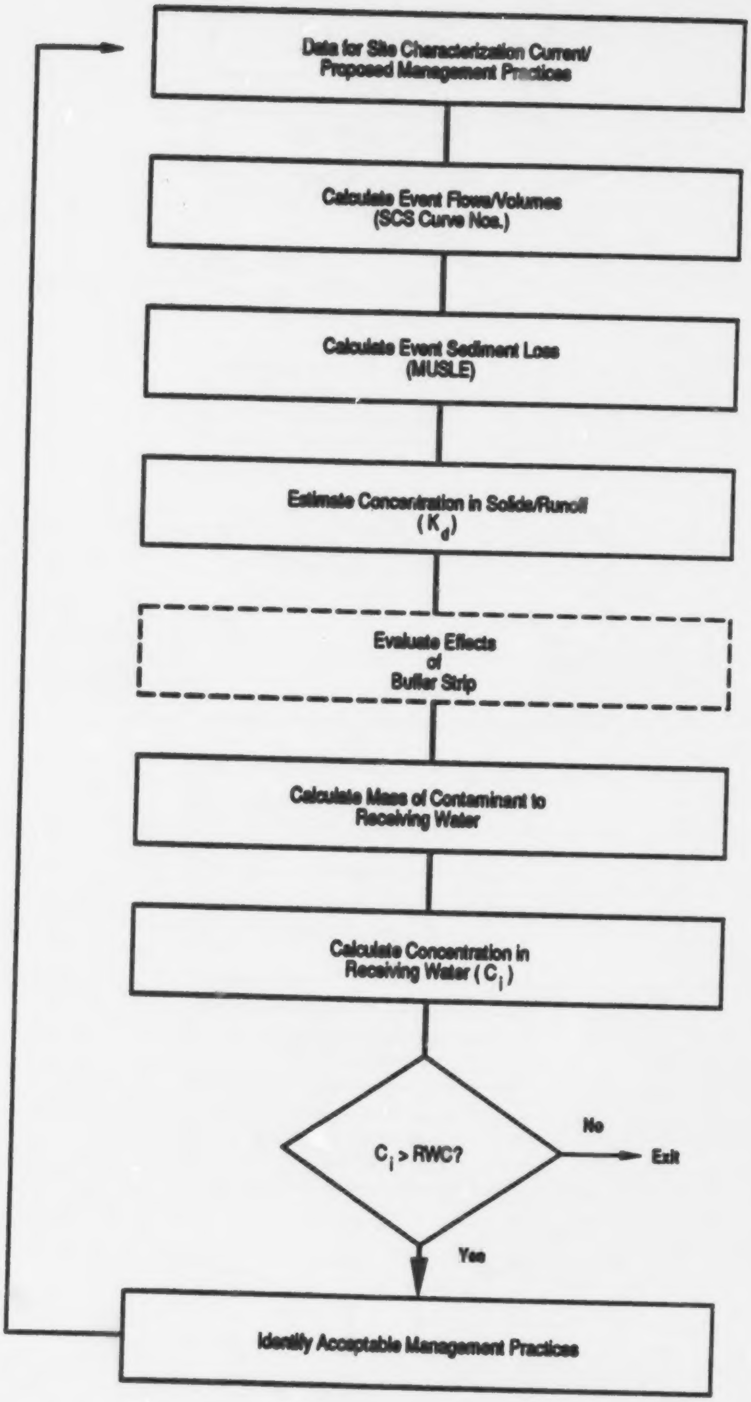

Data for Site Characterization Current/
Proposed Management Practices
Calculate Event Flows/Volumes
(SCS Curve Nos.)
Calculate Event Sediment Loss
(MUSLE)
Estimate Concentration in Solids/Runoff
(K_d)
Evaluate Effects
of
Buffer Strip
Calculate Mass of Contaminant to
Receiving Water
Calculate Concentration in
Receiving Water (C_i)
C_i > RWC?
No
Exit
Yes
Identify Acceptable Management Practices

FIGURE 6-2b

Flow Chart for Estimating Event Mean Concentrations
As Addressed by the Methodology

contaminants, not nutrients. Therefore, consideration of species such as nitrate deals only with the health implications, not eutrophication.

For Tier 1, the concentration in the receiving water is equated to the ratio of the mass of contaminant added to the site sludge management area each year to the annual flow of the receiving water. This concentration presents the upper boundary. In Tier 2, the average level of contaminant in the sludge over the life of operation is first computed. The computation differs if single or multiple applications occur. Once the long-term average levels in the SMA are known, the average annual solids loading rate from the SMA can be computed. This is accomplished using the univeral soil loss equation (USLE). The effects of a buffer zone between the SMA and the receiving water body can also be calculated.

The receiving water analysis for constant loading may be conducted for a stream, lake or estuary and involves a simple dilution calculation, assuming complete mixing. If applicants desire to pursue a more rigorous evaluation, they may apply receiving water models that emphasize analytic solutions to simplified systems (O'Conner and Mueller, 1981). The latter are described in Appendix 4. Decay or transformation processes that would decrease the amount of chemical in the system are neglected to provide conservative results. Instantaneous equilibrium given by a linear isotherm (where the proportionality constant is the distribution or partition coefficient) is assumed to govern the distribution of dissolved vs. adsorbed chemical.

Tier 1 corresponds to direct discharge of all sludge-applied contaminants to an initially mixed zone near the point of loading. If the predicted concentrations (x_a) from a Tier 1 analysis (near field mixing) exceed the criteria (RWC), more complex equations are provided in Tier 2 that take into account infiltration of dissolved contaminants and degradation in SMA and sediment deposition in the buffer zone. Input parameters for the Tier 2 analysis are derived by selecting literature values on the basis of site characteristics. If predicted concentrations from the Tier 2 analysis exceed the criterion, the user may choose to conduct a Tier 3 analysis where, although the equations used are the same as in Tier 2, the inputs are obtained directly from site-specific data. At any time in the process, the user may elect to consider alternative management practices as shown in Figure 6-2a. When such practices reduce predicted contaminant concentrations to acceptable levels, they are written into the regulations/permit as required. Possible practices include runoff diversion ditches, mandatory depths of incorporation and contour plowing.

The flow chart for calculation of event average contaminant loads is shown in Figure 6-2b. In this methodology, the Soil Conservation Service's Curve Number approach is used to estimate event surface runoff from the SMA. Solids loss rates are then calculated using the modified USLE (MUSLE). The total quantity of the contaminant in the sludge is then assigned to a dissolved or adsorbed fraction using a partition coefficient, and the mass loadings of dissolved and adsorbed contaminant to the receiving water are calculated. The effects of a buffer zone on these loadings can also be assessed.

Event loadings are considered in the methodology to provide an estimate of acute exposure. The loading is assumed to be completely mixed in a volume of water equal to the stream flow times the duration of the event. Once again, if an applicant chooses, a more rigorous approach can be taken allowing for dispersion and sedimentation.

This methodology has been constructed from principles and process descriptions typically used to describe the movement of contaminants from source area to receiving waters and thence to compliance points during nonpoint source runoff events. Equations have been simplified and certain assumptions have been made to provide tractable solutions. These are discussed in the next section. To adapt these equations to the sludge runoff problem, modifications must also be made to equation parameters. In some cases, there is considerable uncertainty concerning the extent of modifications. The method intends to yield an initial estimate of loads and concentrations. More detailed analysis in areas of uncertainty may be desirable.

6.2. ASSUMPTIONS

A number of assumptions were required to develop the surface runoff pathway portion of the methodology. This section first discusses assumptions for the runoff (or loading) algorithms. These are organized by long-term and short-term analyses. A discussion of the assumptions used in the receiving water algorithms follows.

6.2.1. Loading Algorithm Assumptions.

The important assumptions utilized for the development and application of the sludge surface runoff loading algorithms are listed in Table 6-1.

6.2.1.1. LONG-TERM ANALYSIS

-- The major assumption for estimating long-term average concentrations is that these concentrations are produced primarily by the release of contaminants from particulate material that has been transported from the SMA and deposited in the receiving water body. In Tier 1, all contaminants are assumed to be transported to the receiving water each year. Thus, no infiltration losses, degradation or settling in the buffer zone are considered. All contaminant is subsequently assumed to be dissolved in the receiving waters.

TABLE 6-1

Surface Runoff Methodology Assumptions

Functional Area		Assumption	Ramifications
Long-Term Concentrations			
Tier 1		All contaminant applied on an annual basis is transported to the receiving water in a dissolved form.	Provides an extremely conservative estimate since no losses are accounted for.
Tier 2/3	General	Loadings to the receiving water can be described as a function of solids loading.	Mechanistically inappropriate for contaminants with low partition coefficients. Effects of management on sediments will not reflect the efficiency of treatment for these contaminants.
	Source Area	Contaminant concentration associated with solids is the total concentration in the SMA on a dry weight basis.	Ignores partitioning that may affect the arrival time but not the total mass flux to the receiving water.
		No settling of particles in the SMA, gross erosion reaches the edge of field.	Maximizes contaminant loss.
	Buffer Zone	No enrichment or preferential transport.	Gives a lower end estimate of contaminant loading to receiving water.
		Buffer efficiency is constant over the life of operation.	Underpredicts contaminant loading to receiving water by assuming that buffer is well maintained.

TABLE 6-1 (cont.)

Functional Area		Assumption	Ramifications
Event Concentrations			
Tier 1		All contaminant added in a year of application is lost in a single runoff event.	Provides extremely conservative estimate with no provision for losses or incomplete mobilization.
Tier 2/3	Source Area	No kinetically limited release of contaminant from sludge/soil mixture, i.e., total contaminant concentration, is fully equilibrated into adsorbed and dissolved phases.	Maximizes contaminant concentration available for runoff in dissolved phase, thereby maximizing landings.
	Buffer Zone	No enrichment or preferential transport.	Gives a lower-end contaminant loading to stream in the presence of a buffer zone.
		Settling only; no erosion occurs from buffer zone during events.	Underpredicts contaminant transport to stream by neglecting build-up in buffer zone.

In Tiers 2 and 3, the deposited particulates are assumed to contain the same concentrations of contaminants as the long-term average levels in the SMA. This concentration is higher than actually would be found on the solids alone. Therefore, long-term concentrations in receiving water bodies are a function of the mass loading of contaminant from the SMA associated with solids and the subsequent dissolution. The only contribution to dissolved contaminant comes from desorption of contaminant from entrained particles.

It is assumed that no enrichment or preferential transport of solids takes place in the SMA. In reality, during the erosion process, smaller, less dense particles are more easily transported to the edge of the field than heavier particles. Contaminants are more commonly associated with these lighter, finer particles as they usually consist of clays and organic matter. Therefore, the concentration of contaminant by weight is higher in these particles causing an apparent "enrichment" over the concentrations observed in the in situ soils. Normally, when calculating erosion-associated contaminant loss, this effect must be accounted for, unless sediment mass transport is calculated for various particle sizes. Because there are no data to quantify enrichment from SMAs, this process has not been accounted for in this methodology. Since the assumption is that all eroded material is transported to the edge of the field, loadings to the receiving water are maximized.

The same assumption is made if the effects of a buffer zone are considered in the calculations; no enrichment is assumed in the buffer zone. This assumption would underestimate contaminant transport if some form of enrichment actually does occur. The assumption is also made that the effectiveness of the buffer zone is constant over the entire operating life of the SMA. Normally, the buffer zone would lose its effectiveness over time, as solids and contaminant accumulate there. This assumption, therefore, will also tend to yield an underprediction of the mass flux of contaminant through the buffer zone. By calculating loads to the receiving water body with and without the buffer zone influence, one can bracket the effects of this assumption.

Other less important assumptions have also been made in developing the methodology. These assumptions deal primarily with the use of certain conventions or simplifications of equations so that analytical solutions can be developed. These assumptions, discussed below, do not necessarily lead to conservatism or other bias in the results.

In the development of long-term loadings, it is assumed that the USLE is an appropriate algorithm for computing average annual solids losses from SMAs. The USLE was originally developed to predict annual soil loss from croplands east of the Rocky Mountains. It is assumed that the 'K' and 'C' parameters can be adjusted for sludge incorporation or sludge surface disposal to yield appropriate solids loss estimates. The values of these parameters are improving as studies are completed on erosion of sludge-amended soils. Parameter selection is discussed in Section 6.4.

In the calculation of long-term average bulk density, it is assumed that the sludge mineralization process results in a material of the same bulk density as the original soil. Therefore, over long periods of time after cessation of application, the soil would return to its original bulk density. This assumption does not have a great impact on the outcome since the sludge and soil bulk density differ only by a factor of less than 2.

In the calculations of the effects of the buffer zone, an algorithm for the effects of buffer zone on soil loss from construction sites is used. It is assumed that the buffer strip would affect a similar reduction in soil and sludge solids loss from SMAs. Young et al. (1980) measured (on the average) 19.5 and 22.1% of the solids from feedlot runoff passing through vegetated buffer strips of 27.43 m (average of corn, orchard grass and sorghum/Sudan grass plots) and 21.34 m (average of corn and oats plots). The predictions from the equation used in this methodology would be 37 and 39%, respectively. Edwards et al. (1983) measured 50 and 27% of the solids from a feedlot passing through tall fescue buffer strips of 30 m and 60 m, respectively. Methodology predictions would be 36 and 31%, respectively. Asmussen et al. (1977), however, measured only 4% (average value) of soil particles from a Cowarts loamy sand soil moving through a 24.4-m grassed waterway. The methodology prediction would be 38%. It appears that for animal waste solids, therefore, the algorithm used in the methodology gives reasonable results. The predicted results do not agree well with the observations of Asmussen et al. (1977). A loamy sand soil, however, can have 70-95% of the particles in the sand size fraction. Sand-sized particles would not be as easily transported through a buffer as smaller, less dense sludge or fecal particles.

6.2.1.2. EVENT ANALYSIS -- Similar assumptions are made for the estimation of short-term concentrations. In Tiers 2 and 3, the single most important assumption is that the contaminants will be mixed into a volume of water equivalent to the receiving waterflow for the duration of the storm event. Therefore, the proper selection of the storm rainfall depth and the diluting flow in the stream are important. The magnitude of the rainfall event chosen has a direct bearing on the magnitude of the pollutant loading event. This, together with the streamflow chosen, directly influences the calculated instream concentration. In the absence of specific guidelines for choosing recurrence intervals, a 1-in-5-year design storm together with a 1-in-5-year mean daily low flow are used as examples in this document. The recurrence interval of the instream concentration resulting from this joint event is not determined here, but may be estimated using the approximate analytical method of Di Toro (1984) or by site-specific rainfall-runoff simulation.

Another important issue is the duration associated with the instream criterion. For instance, if a 24-hour LC_{50} is the criterion, then the rainfall and streamflow event should also be of 24-hour duration; that is, the duration of the rainfall and streamflow event should be selected to match the criterion.

Within the source area, mass fluxes in both runoff water (dissolved phase) and transported sediment/sludge particles (adsorbed phase) are considered. The major assumption is that the equilibrium between the dissolved and adsorbed phases is achieved instantaneously and can be completely specified by an adsorption partition coefficient. If in fact the dissolution of contaminants from the soil/sludge mass is kinetically limited, this assumption will tend to overpredict dissolved phase concentrations during the runoff event. The total mass flux from the SMA will also be overpredicted. Thus, this assumption produces an environmentally conservative loading estimate.

In the buffer zone, calculations for short-term concentrations (as in the long-term concentration analysis) assume that no enrichment occurs during transport. In addition, no erosion is assumed to occur from the buffer zone. These assumptions could bias the estimated mass fluxes toward lower-than-expected values. This set of assumptions, used in conjunction with the "no buffer zone" assumption, will tend to bracket the true values.

Additional assumptions of the event mean loading algorithms are discussed in the following paragraphs.

Runoff from the SMA is predicted using the SCS Runoff Curve Number approach. This approach has never been applied to this particular problem set. It was developed on data from many years of storm flow records of agricultural watersheds with a wide variety of soil types. It is assumed that the curve number, CN, can be changed to reflect the lower runoff resulting from the additions of organic matter to soils (see Section 6.4.). It is also assumed that the MUSLE used to predict event sediment loadings is appropriate. If the USLE is appropriate for annual sludge/soil loss predictions, this seems a reasonable and logical extension.

The algorithms for the estimation of dissolved and adsorbed contaminant loss from SMAs was developed by Haith (1980). They were originally designed to predict pesticide losses from agricultural fields. The algorithms assume that runoff is generated from the top 1 cm of soil and that contaminant below that depth is unavailable for runoff. Partitioning of the chemical is assumed to be instantaneous, linear and completely reversible. It is assumed that the rainfall is sufficient to fill the available water capacity of the top centimeter of soil and that the available dissolved contaminant is distributed into the runoff, percolation and residual soil water components by the fractions of the rainfall going to each. The calculation of the runoff rate assumes a trapezoidal hydrograph.

The reduction of solids through the buffer zone is accounted for through use of a sediment delivery ratio. It is also assumed that the resistance to flow through the buffer strip is not affected by the slope of the buffer or the type of vegetation. The approach where the flow is affected by the slope and other properties of buffer zone requires an iterative solution for the flow rate through the buffer (Khaleel et al., 1979). Since that level of detail was not warranted in this methodology, the only management variable for the buffer zone is the length.

6.2.2. **Assumptions in Receiving Water Analysis**. This section describes assumptions made to determine maximum concentrations that could result from predicted mass loadings from the SMA.

The Tier 1 analysis assumes complete mixing of contaminants into the receiving water. Therefore, whether a stream, lake or estuary, the concentration is defined as the ratio of the mass of contaminant input to the total throughput of water for the time period of interest. For long-term exposures (chronic exposure criteria), the period of interest is 1 year (i.e., contaminant mass added/year and total annual flow volume). For the event analysis, the period of interest is the duration of the event (i.e., mass of contaminant carried in event runoff, and total flow of the receiving water during the storm event). This assumption overpredicts concentration in that it does not allow for dispersion, and underpredicts concentration where mixing is poor and exposure zones of interest are in the path of the contaminant plume. The analyst has the choice of using the total mass of contaminant (dissolved and adsorbed) or making independent comparisons with relevant criteria for each phase. Currently, there are no criteria for sediments and therefore, the adsorbed phase cannot be evaluated directly. The evaluation of individual sites considering complex receiving water dynamics requires a significantly different set of assumptions that reflect the type of water body under consideration. While this approach will not be employed to evaluate and select best management practices for the regulatory program, a procedure is offered for guidance in Appendix 4. The assumptions for this approach and the procedure are described to illustrate the approach applicants may take.

6.3. CALCULATIONS

The evaluation of the impact of surface runoff from sludge management areas involves the prediction of runoff, sediment loss and the concentrations (or loadings) of contaminants in each of these phases. From a health-based perspective, it may be important to predict both long-term average concentrations (for chronic toxicity or carcinogenic risk analyses) and short-term (event) concentrations (for acute toxicity analyses). Therefore, it is important to develop algorithms that predict both long-term (average annual) and short-term (event) loadings from the sludge management areas into receiving waters.

The algorithms for predicting runoff and sediment loss from these areas utilize the Universal Soil Loss Equation (or its modifications) and the Soil Conservation Service Curve Number Hydrology computations.

Long-term loadings are discussed first, followed by event loading algorithms. A discussion of the Tier 1 approach is given first, followed by a discussion of the Tier 2/Tier 3 approaches.

6.3.1. Tier 1. By design, the Tier 1 methodology is a simple construct to screen out sludge land application practices that clearly will not pose significant risks to human health or the environment. The assumptions made in Tier 1 are intentionally conservative so that risky sites are not waived from further scrutiny. As a tradeoff, many alternatives may proceed to Tier 2 before it can be shown that they also will pose no significant risks.

The Tier 1 method addresses both long-term exposure and acute events. In both cases, it is assumed that the runoff pathway is the only transport route for physical removal of contaminant from the system. As a consequence, soil contaminant concentrations will increase until annual runoff losses equal the mass of contaminant applied each year. (No provision is made for degradation.) Hence, the flux (F_i) of contaminant in runoff is described:

$$F_i = N_i(A_s) \qquad (6\text{-}1)$$

where:

F_i = annual mass flux of contaminant (mg/ha-year)
N_i = contaminant concentration in sludge (mg/kg)
A_s = sludge application rate (kg/ha-year)
ha = hectare

The total maximum mass of contaminant (M_i) lost to surface water is then defined:

$$M_i = F_i(\text{SMA}) = N_i(A_s)\text{SMA} \qquad (6\text{-}2)$$

where:

SMA = sludge management area (ha)

The long-term exposure concentrations (C_i) in the receiving water are calculated on the basis of the volume of water (V) in which the transported mass will be assimilated:

$$C_i = M_i/(1000\ V) \qquad (6\text{-}3)$$

where:

C_i = long-term exposure concentration (mg/ℓ)
M_i = annual mass of contaminant transported (mg/year)
V = volume of dilution water (m^3/year)
1000 = conversion factor to equate V to liters

Combining Equations 6-2 and 6-3,

$$C_i = \frac{N_i(A_s)\text{SMA}}{1000\ V} \qquad (6\text{-}4)$$

If the receiving water is a stream or river, V, is determined as the total annual flow [i.e., the product of volumetric flow rate, Qf (m^3/sec) and 31,536,000 (sec/year)]. For estuaries and lakes, V would be the annual throughput volume defined as the product of the sum of the outflow volumetric rates, Qf (m^3/sec) and 31,536,000 (sec/year).

The calculated concentration (C_i) is compared with the chronic reference water concentration (RWC). If it exceeds the RWC, a Tier 2 analysis of long-term exposure is required. If the concentration is less than the RWC, the long-term analysis can be terminated for that contaminant.

The event exposure analysis differs from the long-term exposure analysis in that it focuses on the concentrations resulting from runoff from a single storm event and compares them with acute RWC. For Tier 1, it is assumed that the total mass of contaminant applied to the field in a year is transported by the design storm event as indicated:

$$M_i \text{ event} = N_i(A_s)SMA \qquad (6\text{-}5)$$

where:

M_i event = total mass of contaminant transported in a given storm event (mg)

N_i = contaminant concentration in sludge (mg/kg)

A_s = sludge application rate (kg/ha-year)

SMA = area to which sludge is applied (ha)

The concentration of contaminant in the receiving water as a result of a given storm event is determined:

$$C_i \text{ event} = M_i \text{ event } (1000\ V) \qquad (6\text{-}6)$$

where:

C_i event = event concentration (mg/ℓ)

M_i event = mass of contaminant transported in a storm event (mg)

1000 = conversion of V from m^3 to ℓ

V = volume of water in which M_i event is diluted (m^3). For rivers, V is the product of the mean flow rate and the duration of the storm. For estuaries and lakes, V would be the product of the throughput or drainage volumetric rate and the duration of the storm event

The computed C_i event is compared with the acute RWC. If C_i event exceeds the RWC, a Tier 2 analysis is required. If C_i event is less than the threshold, no further event analysis is required for that contaminant.

6.3.2. Tier 2/3.

6.3.2.1. LONG-TERM AVERAGE LOADINGS -- As previously mentioned, contaminants from SMAs are introduced into receiving waters by both runoff and erosion. These loadings tend to occur over relatively short periods of time over the year. Therefore, the time frame over which the dissolved constituents resulting directly from the event influence the long-term levels of contaminant in the system is of short duration, especially in the case of streams. In contrast, the system is typically in an "interstorm" state. The levels of contaminants in receiving waters during such periods are derived from subsurface flows, interflows or from dissolution of solid contaminants that have been deposited in-stream following major storm events. Since this analysis is limited to determining the impact of surface runoff only, the issue of interflows or subsurface flows is not addressed. Such pathways should not yield significant loads of contaminants that interact with soils. Contaminants with an affinity for soil particles are more likely to be found in sludges, since soluble compounds are typically lost in the wastewater effluent. Exceptions would be low molecular weight organics with low partition coefficients (K_d), or anionic species such as nitrates that form as sludge ages. For this analysis it is assumed that long-term average concentrations of contaminants in receiving waters can be estimated based on predictions of average annual sediment loss.

Thus, the problem of predicting long-term average concentrations reduces to the prediction of the solids loading rate from the sludge management area. More specifically, the emphasis is on the average loading rate over the life of the project, and not in year-to-year values.

6.3.2.1.1. Erosion Loss Algorithm -- An appropriate way to compute an average annual solids loading rate is to use the USLE (Wischmeier and Smith, 1978). The USLE is an empirical function designed to predict sheet and rill erosion losses from cropland. By judicious parameter selection (see Section 6.4.1.), the algorithm should also be capable of predicting erosion from sludge management areas.

The algorithm is as follows:

$$X_e = 2.24R\ K\ (LS)\ C\ P \tag{6-7}$$

in which:

X_e = sediment loss rate (metric tons/ha-year)
R = the "erosivity factor" (year-$_1$)
K = the "erodibility factor" (metric tons/acre-year-unit 'R')
LS = the "topographic or slope/length" factor, dimensionless
C = the "cover management" factor, dimensionless
P = the "supporting practice" factor, dimensionless

A more detailed discussion of factors in USLE is found in Appendix 2.

6.3.2.1.2. Estimation of Contaminant Concentration in _in situ_ Sludge and Soil -- Repeated applications of sludge will result in the gradual elevation of contaminant levels in the sludge management area. These concentrations will continue to rise until, at some point, the losses from the system (e.g., through erosion, volatilization, biodegradation) equalize the input. At this point a "steady-state" level will result. Under certain conditions, this steady-state level might not be reached over the life of the facility. An appropriate level to use for long-term loading calculations would be the maximum soil contaminant level occurring during the life-of-operation of the facility. An expression for this level is:

$$M_m = \frac{k_2}{k_1}\left(1-e^{-k_1 \Delta t}\right) \tag{6-8a}$$

where:

M_m = the maximum contaminant mass per area of soil in the SMA (mg/ha)

Δt = the elapsed time since the beginning of operation (notice Δt cannot equal zero)

k_1 = a lumped first-order loss rate of the contaminant (yr^{-1}) i.e. $k_1 = k_{1i} + k_{1R} + k_{1D}$

k_2 = $F_i - k_o$

in which:

F_i = the contaminant loading rate to the SMA (mg/ha-yr) and
k_o = a lumped zero-order loss rate of the contaminant (mg/ha-yr).

For most sites, there will be no zero-order losses and $k_2 = F_i$. If infiltrate concentrations are solubility limited, losses may be zeroth order and defined by:

$$k_o = XR_c\ (10^{10}) \qquad (6\text{-}8b)$$

where:

k_o = a lumped zero-order loss rate of the contaminant (mg/ha-yr)
X = the leachate concentration (mg/cm^3)
R_c = the recharge rate (m/yr)

Three first-order loss mechanisms are likely to be encountered: infiltration, surface runoff and degradation. If equilibrium between the soil and water is assumed, the first-order loss for infiltration can be described by:

$$k_{1i} = \frac{R_c}{(B\ d\ K_d)}(10^2) \qquad (6\text{-}8c)$$

where:

k_{1i} = the first-order loss rate coefficient for infiltration (yr^{-1})

R_c = the recharge rate (m/yr)

B = the bulk density (g/cm^3)

d = is the depth of incorporation (cm)

K_d = the partition coefficient (cm^3/g)

Again, if infiltrate concentrations are thought to be solubility limited, a zeroth order rate is more appropriate. The first-order loss term for surface runoff is:

$$k_{1R} = \frac{X_e}{(Bd)}(10^{-2}) \qquad (6\text{-}8d)$$

where:

k_{1R} = the first-order loss rate coefficient for surface runoff losses (yr^{-1})

X_e = the calculated sediment loss rate (t/ha-yr)

B = the bulk density (g/cm^3)

d = the depth of incorporation (m)

The case of first-order degradation is described by:

$$k_{1D} = \lambda \qquad (6\text{-}8e)$$

where:

k_{1D} = the first-order loss rate coefficient for degradation (yr-1)

λ is obtained from literature values or derived empirically (yr-1)

Several assumptions must be made to use equation 6-8a. The first is that any loss process (e.g., volatilization, leaching, erosion, degradation) can be represented by a zero-order or first-order approximation. The second is that F_i must be greater than k_o so that k_2 is not negative. A third is that the background levels are negligible compared with the steady-state level.

If no first-order loss term is appropriate or available, then equation 6-8a cannot be used. The solution for multiple application when only a zero order loss term is known is as follows:

$$M_m = \frac{1}{2}(F_i - k_o)\Delta t \qquad (6\text{-}9a)$$

Another situation that might arise is the single application of a large quantity of sludge. The level of contaminant is initially highest and tapers off with time. The expression for the average contaminant level in the SMA if both zero- and first-order losses are considered is:

$$M_m = \frac{k_o}{k_1^2 \Delta t} + \frac{M_o}{k_1 \Delta t} (1 - e^{-k_1 \Delta t}) - \frac{k_o}{k_1} \qquad (6\text{-}9b)$$

where M_o is the initial mass loading in kg/ha, or if no first-order decay is considered:

$$M_m = M_o - \frac{k_o \Delta t}{2} \qquad (6\text{-}9c)$$

Care must be taken in using 6-9b and c, as at some time the equations will produce a negative contaminant level. If this occurs, M_m should be taken as:

$$M_m = \frac{\Delta t'}{\Delta t} M_{\Delta t'} \qquad (6\text{-}9d)$$

in which:

$\Delta t'$ = the elapsed time in which M_m becomes zero

$M_{\Delta t'}$ = the average contaminant level from initial application until that time.

The variable $\Delta t'$ can be determined by:

$$\Delta t' = \ln \left[1/(1 + \frac{M_o k_o}{k_1})(-k_1) \right] \qquad (6\text{-}9e)$$

if equation 6-9b is used, or by:

$$\Delta t' = \frac{2\, M_o}{k_o} \qquad (6\text{-}9f)$$

if equation 6-9c is used to calculate $M_{\Delta t'}$.

Once the contaminant level in the facility is known, a concentration must be calculated. This is done by dividing the contaminant level by the affected mass of soil or sludge. For surface applications, the affected mass is the bulk density of the sludge times the depth of sludge. For soil incorporation, the affected mass is the average bulk density of the sludge and soil mixture times the incorporation depth.

The mass of affected soil is then calculated by multiplying the average bulk density by the affected soil/sludge volume (the application area times the incorporation depth).

The maximum concentration, C (mg/kg), of contaminant is then the quotient of the total maximum contaminant mass per area of soil M_m (kg/ha) and the soil/sludge mass:

$$C = 10M_m/(d\ B) \qquad (6\text{-}10)$$

where:

d = the incorporation depth (cm)
B = the soil/sludge bulk density (g/cm^3)
10 = conversion factor to adjust for units

6.3.2.1.3. Annual Erosion Contaminant Loss -- The maximum annual loss of the contaminant from the SMA, L_o (kg/yr), is then

$$L_o = 10^{-3}\ X_e\ C\ (SMA) \qquad (6\text{-}11)$$

in which:

SMA = area of land to which sludge is applied (ha)

X_e = the sediment loss rate (mt/ha-yr)

C = the long-term concentration (mg/kg)

10^{-3} = a conversion factor to allow for different units

6.3.2.1.4. Effect of Buffer Zone -- Conservatively, it can be assumed that the buffer zone has only a short effective life and that the loadings generated from the SMA enter the receiving water directly. If the buffer zone is maintained, however, it can be an effective means of reducing the solids loads from the SMA. The reduction of sediment load as the runoff moves across the buffer is quantified in a factor known as the sediment delivery ratio.

Only limited work has been done on the attenuation of solids by vegetative buffers. For the level of detail of the long-term analysis, the only relationship of any particular value seems to be that presented in Mills et al. (1982). In their formulation, the sediment delivery ratio (S_d) is a function of the length of the buffer strip normal to the direction of runoff:

$$S_d = (3.28L_b)^{-0.22} \qquad (6\text{-}12)$$

in which:

L_b = the length of the buffer strip (m).

Therefore, the maximum annual load of contaminant delivered to the stream through an intervening buffer zone, Le (kg/yr), would be:

$$L_e = L_o\ (S_d) = 10^{-9}\ X_e\ C(SMA)(S_d) \qquad (6\text{-}13)$$

This formulation assumes that there is no enrichment of the contaminant concentration across the buffer strip. That is, there is no preference of contaminant for finer, more easily transported sludge particles.

6.3.2.2. EVENT LOADINGS -- During the rainfall/runoff event, contaminants can be transported both in the dissolved and adsorbed phases. The loading to the receiving water body depends upon volume of runoff and sediment mass transported as well as concentrations in each phase. In this methodology, runoff is predicted using the SCS Curve Number Hydrology relationship and sediment transport by the MUSLE (Williams, 1975; Haith, 1985).

6.3.2.2.1. Prediction of Runoff Volumes -- Runoff from a storm event on a given area depends primarily on two factors: the infiltration properties of the soil and the water status of the soil at the time that the storm occurs. The SCS method accounts for these factors.

The depth of runoff from the watershed area is estimated by the following equation:

$$D_R = \frac{(R_t + M_t - 0.2S)^2}{(R_t + M_t + 0.8S)} \qquad (6\text{-}14)$$

where:

D_R = depth of runoff in the watershed area (cm)
R_t = depth of total rainfall for the storm event (cm)
S = watershed retention parameter (cm)
M_t = depth of snowmelt during the storm event (cm)

S, the watershed retention parameter, is calculated using:

$$S = 2.54\ [(1000/CN)-10] \qquad (6\text{-}15)$$

where:

CN = the SCS Runoff Curve Number (dimensionless).

The storm runoff volume can be calculated by:

$$Q = 100(SMA)\ D_R \qquad (6\text{-}16)$$

where:

Q = total storm runoff volume (m^3)
SMA = SMA area (ha)
D_R = depth of runoff (cm)

To use the MUSLE, the peak storm runoff rate must also be known.

6.3.2.2.2. Estimation of Peak Storm Runoff -- In order to estimate peak storm runoff a hydrograph shape must be assumed. Commonly, a triangular or trapezoidal shape is used. A trapezoidal hydrograph is used here. The equation for the peak runoff rate is

$$q_p = \frac{0.028\ (SMA)\ D_R\ R_t}{T_r\,(R_t - 0.2S)} \qquad (6\text{-}17)$$

where:

q_p = peak runoff rate (m^3/sec)
SMA = watershed area (ha)
R_t = rainfall depth in the storm event (cm)
D_R = runoff depth from storm event (cm)
T_r = storm duration (hr)
S = water retention parameter (cm)

For development of the above equation see Haith (1980).

6.3.2.2.3. Single Event Sediment Loads -- Soil erosion is governed by two processes: detachment of soil fines and transport of soil fines to the receiving water body. Detachment of soil fines can be accomplished by erosive rainfall or by shear forces at the soil surface created by surface runoff. One of the shortcomings of the USLE is that it does not explicitly consider transport nor detachment by runoff. Williams (1975) modified the USLE by replacing the "R" factor with a "runoff energy" factor to provide more accurate sediment loss prediction for single storm events. In addition, this modification eliminates the need for the sediment delivery ratio. The form of this modification is:

$$x_s = 11.8 \, (Q \, q_p)^{0.56} K(LS)C \, P \tag{6-18}$$

where:

x_s = sediment loss from a single storm (mt)
Q = volume of runoff (m^3)
q_p = peak runoff (m^3/sec)

Other terms are as previously defined in Equation 6-7.

6.3.2.2.4. Determination of Contaminant Runoff Loss -- The basis for this analysis is that the contaminants in the sludge will partition into soluble (dissolved) and insoluble (adsorbed) fractions when water is mixed with the sludge/soil mass. The development also assumes that runoff is generated from the top centimeter of the soil/sludge mixture and that within that centimeter, equilibrium partitioning is attained. For event simulations, the maximum concentration realized over the life-of-operation of the facility should be used. For a single application, this concentration is the initial contaminant concentration in the sludge. For multiple applications, the following is used to estimate the maximum contaminant level for degradable constituents (P_t, kg/ha):

$$P_t = \frac{k_2}{k_1}(1 - e^{-k_1 \Delta t}) \qquad (6\text{-}19)$$

where k_2 and k_1 are loss rate constants as defined for Equation 6-8. For nondegradable constituents, the maximum contaminant level is calculated as follows:

$$P_t = (F_i - k_o)\,\Delta t \qquad (6\text{-}20)$$

where F_i and k_o are as defined in Equation 6-2.

Since the following algorithms assume runoff occurs only from the top centimeter, the value of P_t above should be divided by the incorporation depth if tilling occurs, or the sludge depth if applied to the surface before being used.

Therefore, Equations 6-19 and 6-20 are rewritten as:

$$P_a = \frac{P_t}{d} = \frac{k_2}{dk_1}(1-e^{-k_1 \Delta t}) \qquad (6\text{-}21)$$

and

$$P_a = (F_i - k_o)\,\frac{\Delta t}{d} \qquad (6\text{-}22)$$

respectively, where:

P_a = mass of contaminant in the top centimeter of sludge or soil (mg/ha-cm)

$k_2 = F_i - k_o$ (mg/ha-yr)

F_i = contaminant loading rate to the SMA (mg/ha-yr)

k_o = lumped zero-order loss rate constant (mg/ha-yr)

d = depth of incorporation or of sludge if applied to surface (cm)

k_1 = lumped first-order loss rate constant (1/yr)

Δt = elapsed time since beginning the operation (yr)

To determine the magnitude of runoff loss, the quantity of adsorbed and dissolved contaminant is first determined. Total contaminant is the sum of the adsorbed and dissolved fractions:

$$P_a = A_a + D_a \tag{6-23}$$

The adsorbed quantity A_a is given by the following:

$$A_a = [1/(1 + \theta/K_dB)]\ P_a \tag{6-24}$$

while the dissolved fraction, D_a, is as follows:

$$D_a = [1/(1 + K_dB/\theta)]\ P_a \tag{6-25}$$

The loss of adsorbed contaminant is given by:

$$P_{xt} = [x_s/100(SMA)B]\ A_a \tag{6-26}$$

and the dissolved contaminant loss is as follows:

$$P_{qt} = [D_R/(R_t + M_t)]\ D_a \tag{6-27}$$

In the above equations

A_a = adsorbed contaminant mass in top centimeter of soil (mg/ha-cm)

θ = available volumetric water capacity of the top cm of soil (difference between wilting point and field capacity, dimensionless)

B = soil bulk density (g/cm³)

P_a = total contaminant mass in top centimeter of soil (mg/ha-cm)

D_a = dissolved contaminant mass in top centimeter of soil (mg/ha-cm)

P_{xt} = adsorbed contaminant loss (mg/ha)
P_{qt} = dissolved contaminant loss (mg/ha)
D_R = total storm runoff depth (cm)
R_t = total storm rainfall depth (cm) and
M_t = total snowmelt depth (cm)
K_d = adsorption partition coefficient (cm³/g)
x_s = sediment (mt)
SMA = area of site (ha)

6.3.2.2.5. Effect of Buffer Strip -- Determining the effects of buffer strips is difficult at best, and for large sites may be complicated by the existence of drainage channels. For the purposes of predicting contaminant loss in the buffer strip, the analysis is divided between particulate and dissolved contaminants.

No losses are assumed in dissolved contaminant movement across the buffer strip. This assumption is based on the premise that adsorption is reversible; thus if the contaminant adsorbs to surface soil particles, the same amount of contaminant is desorbed, resulting in no significant net change in soluble levels.

For particulate bound contaminants, the sediment delivery ratio concept is employed using Equation 6-12:

$$S_d = (3.28L_b)^{-0.22} \tag{6-12}$$

where:

S_d = the fraction of sediment load that is transported across the buffer zone (dimensionless)

L_b = the length of the buffer strip (m)

Applying these loss rates to the predicted loadings, yield estimates for the dissolved and adsorbed contaminant losses are as follows. For dissolved contaminants, the mass transport is unchanged and, therefore, from Equation 6-27:

$$P'_{qt} = P_{qt} = [D_R/(R_t + M_t)]\ D_a \tag{6-28}$$

For adsorbed contaminants, the mass transported is modified by applying the delivery ratio to Equation 6-26 yielding the following:

$$P_{xt}' = (S_d)P_{xt} = \{(x_e)(S_d)/[100(SMA)B]\}\ A_a \tag{6-29}$$

P_{qt}' and P_{xt}' have units of mg/ha coming off the buffer strip over the duration of the storm. The total mass of dissolved and suspended solids coming off the buffer strip can be calculated as follows:

$$P_{qt}'' = P_{qt}' \text{ (SMA)} \tag{6-30}$$

$$P_{xt}'' = P_{xt}' \text{ (SMA)} \tag{6-31}$$

where:

P_{qt}'' and P_{xt}'' have units of mg.

6.3.2.3. RECEIVING WATER METHODOLOGY -- The Tier 2/3 approach to receiving water analysis is the same as that for Tier 1 (i.e., the estimated load is divided by the flow of the receiving water for the period of interest as indicated in Equations 6-4 and 6-13).

$$C_i = \frac{M_i}{1000V} = \frac{L_e \ 1000}{V} \tag{6-6}$$

For the event analysis, this can result in three possible values:

1. Dissolved contaminant concentrations based solely on the dissolved portion of the event analysis contaminant load;
2. Particulate contaminant concentration based solely on the adsorbed portion of the event analysis contaminant load; and
3. Total contaminant concentration based on the sum of the above two loads.

Since there are no acute or chronic particulate contaminant criteria, the second calculation cannot be currently evaluated. The third value (the total) is conservative and accounts for subsequent desorption in the receiving waters.

6.3.3. Setting National Criteria, Surface Runoff Algorithms. The objective of applying the surface runoff algorithms in reverse order is to determine a maximum allowable concentration in runoff to meet health criteria in a receiving water body. In general, the receiving water algorithms would be applied first, solving for the contaminant loading rates given receiving water criteria. Once the loading rate is determined, the loading algorithms can be inverted to solve for the maximum contaminant concentration in runoff. The inversion of the methods assumes that the method is first applied in the forward direction and that the hydrologic constants in the equations are unchanged.

6.3.3.1. LOADING ALGORITHMS -- LONG-TERM ANALYSIS -- In this case, the application of the methodology to solve for the contaminant level in the SMA is not difficult. However, because the long-term analysis does not differentiate between the dissolved and adsorbed loadings, only the total concentration of the contaminant in the sludge is necessary, and a concentration from the extraction test is not applicable. Therefore, long-term concentrations can be regulated based upon total concentrations in the sludge.

Knowing the loading rate, L_e, the concentration in the solids can be determined by solving equation 6-13 for C. Thus,

$$C = \frac{L_e\ 1000}{X_e\ (SMA)S_d} \qquad (6\text{-}32)$$

If no buffer was used in the forward analysis, $S_d = 1$. Then equation 6-10 is used with known C to solve for M_m:

$$M_m = \frac{C\ d(B)}{10} \qquad (6\text{-}33)$$

Depending upon the type of application (single versus multiple) and the types of rate constants available (zero or first order or both) Equations 6-9, 6-9a, 6-9b or 6-9c can be solved for either M_o or k_2. F_i can be determined from:

$$F_i = k_2 + k_o \qquad (6\text{-}34)$$

M_o or F_i give the maximum annual contaminant loading rates based upon the maximum loading resulting from an effects threshold value. Maximum concentrations can be calculated by dividing M_o or F_i by the applied sludge dry weight.

6.3.3.2. EVENT ANALYSIS -- Because there are no current particulate or sediment criteria for acute exposures, the event analysis cannot easily be operated in a reverse mode. As a consequence, national criteria will be difficult to establish for acute events. The current methodology can be operated in the forward mode on a trial and error basis to determine limiting concentrations in applied sludge only if the dissolved contaminant levels are considered. An example of this approach is provided in Section 6.6. If it is assumed that leachate contaminant concentrations rise proportional to the sludge contaminant concentrations, the receiving water concentration will change proportional to changes in sludge contaminant levels. Therefore, a forward analysis for a given setting can be made for any given sludge concentration. The resulting receiving water concentrations from dissolved contaminant C_i can be compared with the acute RWC. The ratio of the latter to the former will be the factor required to multiply the sludge concentration to determine the limiting sludge concentration:

$$N_i\ \text{criteria} = [(\text{RWC})/C_i\ \text{test}\ N_i\ \text{test}] \qquad (6\text{-}35)$$

where:

N_i criteria = the sludge concentration criteria (mg/kg)

RWC = the acute exposure reference water concentration (mg/ℓ)

C_i test = receiving water criteria determined from test case (mg/ℓ)

N_i test = sludge concentrations in test case (mg/kg)

6.3.3.3. RECEIVING WATER -- LONG-TERM ANALYSIS -- Operation of the receiving water portion for setting national criteria is based on long-term loadings. Equations 6-4 and 6-6 are solved for the necessary loading to make C_i equal to RWC. For the long-term analysis, Equation 6-4 is converted to

$$F_i = \frac{1000V\ (\text{RWC})}{(\text{SMA})} \qquad (6\text{-}36)$$

where:

F_i = the maximum acceptable annual loading rate for contaminant (mg/ha-yr)

1000 = factor to convert m^3 to ℓ

V = the total annual flow of the receiving water (m^3/yr)

RWC = reference water concentration (mg/ℓ)

SMA = area of the site receiving sludge (ha)

Similarly, for the event analysis, Equation 6-6 is converted to:

$$M_i = 1000V\,(RWC) \tag{6-37}$$

where:

M_i = the maximum acceptable event loading of contaminant (mg)

1000 = factor to convert m^3 to ℓ

V = the event flow for the receiving waters (For sites near small receiving waters it is the product of the mean flow rate and duration of the event. For sites on large receiving waters, where flow is unaffected by the event, it is the product of low flow and the duration of the event.)

6.4. INPUT PARAMETER REQUIREMENTS

The effective application of the surface runoff methodology requires that accurate estimates be made for the algorithm parameters. For many of the parameters involved there are well-developed data bases. Values for these parameters can be found in the appendices to this report. For some parameters, insufficient data exist and thus a judgment on the part of the user will be required. This section contains guidance for the user in exercising this judgment.

6.4.1. Loading Algorithms. The use of the loading algorithms in this methodology requires the estimation of the parameters shown in Table 6-2. The table shows the symbol for the parameter, a description, parameter units needed for the algorithms, and the section of this report in which the evaluation of that particular parameter is discussed. Information on textural properties of the soil (% sand, very fine sand, silt and clay) is

TABLE 6-2

Input Parameters for the Runoff Pathway Methodology

Symbol	Function
f_{oc}	Soil organic content - measured directly or estimated from proposed sludge addition rates (dimensionless)
SMA	Area of land to which sludge is to be applied - derived from site plans (ha)
A_s	Sludge application rate - derived from site operation plan (dry kg/ha-yr)
Δt	Time period over which application is proposed - derived from site operations plan (years)
R_c	Recharge rate - obtained from U.S. Soil Conservation Service or local agricultural extension office (meters/year)
X	Leachate concentration of contaminants - derived from applica- tion of the toxicity characteristic leachate procedure (TCLP) to the sludge (mg/ℓ)
N	Dry weight concentration of contaminant in sludge - derived through direct analysis of sludge (mg/kg)
B	Bulk density of the soil/sludge - use the value of the soil type as provided in Figure 6-3 (g/cm³)
d	Depth of incorporation - determined from method of soil turn- over (cm)
L_b	Length of the buffer zone - derived from the site plan (m)
W	Width of the buffer zone - selected from maps in Appendix 2 (cm)
M_t	Total event snowmelt - obtained from design storm data (cm)
R_t	Total storm rainfall depth (cm)
T_r	Duration of storm event - selected from the maps in Appendix 2 on the basis of the storm with the most erosive runoff (hours)
K_d	Distribution coefficient for the contaminant between soil and water - determined from the literature or by direct experimentation (cm³/g)

TABLE 6-2 (cont.)

Symbol	Function
Q_f	Mean annual stream flow for the receiving water - taken from the nearest USGS gauging station (cm^3/sec)
R_a	Average annual precipitation - derived from the local weather station (cm/yr)
R, K, LS, C and P	Input variables for the universal soil loss equation (USLE) - derived from the site management plan and Appendix 2
θ_{fc}	Field capacity of soil - derived from Figure 6-5 or measured directly (dimensionless)
θ_{wp}	Wilting point of soil - derived from Figure 6-6 or measured directly (dimensionless)

important for estimating other soil parameters. Some parameters in the table that are site-specific or are covered elsewhere are excluded from discussion.

6.4.1.1. USLE PARAMETERS -- The use of either the USLE or the MUSLE requires an estimation of four parameters: K, LS, C and P. In addition, the USLE requires R, while the MUSLE requires R_t and T_r instead. A complete discussion of the estimation of these parameters can be found in Appendix 2, which is excerpted from Wischmeier and Smith (1978).

6.4.1.2. SOIL BULK DENSITY (B) -- Bulk density of the soil is the weight of the solids per unit volume of the bulk soil (including pores). The bulk density of the soil before sludge addition can be determined using the method of Rawls (1983). The method requires textural information concerning the soil (% sand, % silt, clay and organic matter). The mineral bulk density is determined from Figure 6-3. The actual bulk density is then calculated by

$$B = \frac{100}{\frac{\%\ OM}{0.224} + \frac{(100 - \%\ OM)}{Bm}} \qquad (6\text{-}38)$$

in which:

B = soil bulk density (g/cm³)
% OM = percent organic matter
Bm = mineral bulk density (g/cm³) (from Figure 6-3).

6.4.1.3. RUNOFF CURVE NUMBER (CN) -- The data on the effects of sewage sludge land application on surface runoff are limited. Because of this, data from the literature on animal waste disposal were used to supplement them. Kelling et al. (1977) showed decreases in runoff of 37% and 26% when sludge was surface applied at rates of 30 mt/hr and 60 mt/ha (average of 3 years). Long (1979) observed only slight (0-2%) decreases in surface runoff when 45 mt/ha-yr of manure was surface applied over a 4-year period in five

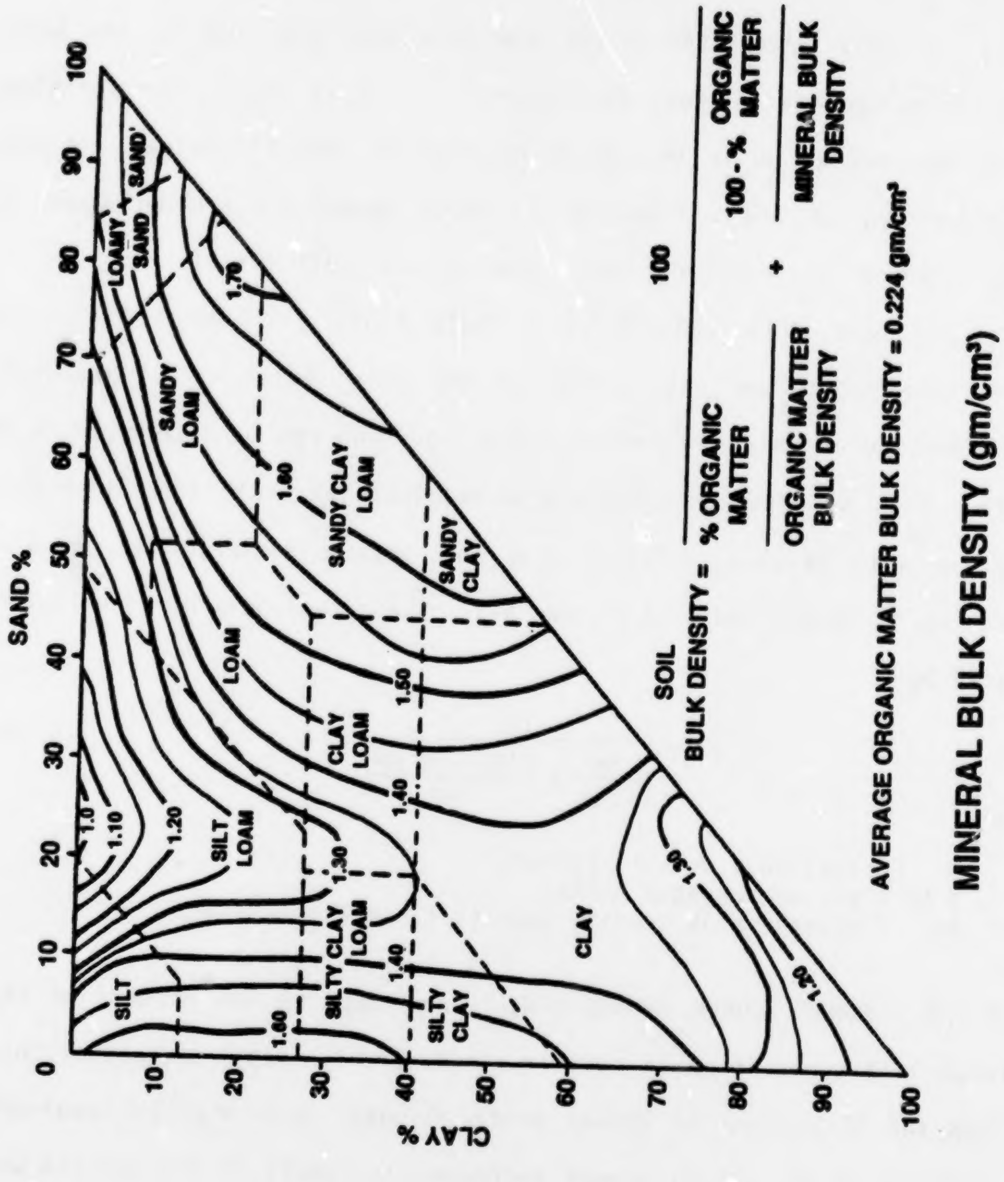


FIGURE 6-3

Mineral Bulk Density of Soils of Varying Textures

Source: Rawls et al., 1983

applications per year. Young (1974) observed decreases of 7 and 2% on corn and alfalfa plots when solid dairy manure was applied at rates of 28 and 56 mt/ha, respectively. Young and Holt (1977), however, showed decreases of up to 62% from a winter application of 44.8 mt/ha of livestock manure. Little difference was observed between surface and plowed-down applications. This indicates that the product of the C and K parameters in the USLE should be roughly halved. For a conservative analysis, however, one could use the unaltered K and C values, which should tend to give an upper bound erosion rate under sludge application conditions. U.S. EPA (1979) recommended an assumption of decrease of 5% in surface runoff when evaluating the effects of animal waste application. A reasonable target would seem to be a 5% reduction in runoff although greater control might be affected. The conservative approach would be to assume no impact of sludge application on the curve number.

Runoff curve numbers are dependent upon antecedent soil water conditions, the relative permeability of the soil and vegetation cover, and management factors. Table 6-3 gives runoff curve numbers for various combinations of the above factors. The table is used by first determining the hydrologic soil group. Descriptions of each group are located at the bottom of the table. Within each crop/management scheme a subrow labeled "Hydrologic Condition" is found. The qualifiers "good," "fair" or "poor" indicate relative management conditions. For instance, under the crop management scenario "small grains, contoured," a "poor" hydrologic condition would be a poor stand of vegetation with breakthroughs in the contours, both of which would increase surface runoff.

The intersection of the crop/management/condition row with the hydrologic soil group column is the curve number for the area. This table,

TABLE 6-3

Runoff Curve Numbers for Hydrologic Soil-Cover Complexes (for Antecedent Rainfall Condition II)[a]

Land Use or Cover	Treatment or Practice	Hydrologic Condition	Hydrologic Soil Group[b]			
			A	B	C	D
Fallow	straight row	--	77	86	91	94
Row crops	straight row	poor	72	81	88	94
	straight row	good	67	78	85	89
	contoured	poor	70	79	84	88
	contoured	good	65	75	82	86
	terraced	poor	66	74	80	82
	terraced	good	62	71	78	81
Small grains	straight row	poor	65	76	84	88
	straight row	good	63	75	83	87
	contoured	poor	63	74	82	85
	contoured	good	61	73	81	84
	terraced	poor	61	72	79	82
	terraced	good	59	70	78	81
Close-seeded legumes or rotation meadow	straight row	poor	66	77	85	89
	straight row	good	58	72	81	85
	contoured	poor	64	75	83	85
	contoured	good	55	69	78	83
	terraced	poor	63	73	80	83
	terraced	good	51	67	76	80

TABLE 6-3 (cont.)

Land Use or Cover	Treatment or Practice	Hydrologic Condition	Hydrologic Soil Group[b]			
			A	B	C	D
Pasture or range						
		poor	68	79	86	89
		fair	49	69	79	84
		good	39	61	74	80
	contoured	poor	47	67	81	88
	contoured	fair	25	59	75	83
	contoured	good	6	35	70	79
Meadow (permanent)						
		good	30	58	71	78
Woods (farm woodlots)						
		poor	45	66	77	83
		fair	36	60	73	79
		good	25	55	70	77
Farmsteads						
		--	59	74	82	86
Roads and right-of-way (hard surface)		--	74	84	90	92

[a] Source: Schwab et al., 1966

[b] A = Lowest Runoff Potential: Includes deep sands with very little silt and clay, also deep, rapidly permeable loess.

B = Moderately Low Runoff Potential: Mostly sandy soils less deep than A, and loess less deep or less aggregated than A, but the group as a whole has above-average infiltration after thorough wetting.

C = Moderately High Runoff Potential: Comprises shallow soils and soils containing considerable clay and colloids, though less than those of group D. The group has below-average infiltration after presaturation.

D = Highest Runoff Potential: Includes mostly clays of high swelling percent, but the group also includes some shallow soils with nearly impermeable subhorizons near the surface.

however, is for antecedent soil moisture condition (AMC) II (which is defined in Table 6-4). To maximize runoff, AMC III would be used, reflecting wet conditions when the storm event begins. The multiplication factors for converting AMC II to AMC III are found in Table 6-4.

6.4.1.4. STORM RAINFALL DEPTH AND DURATION (R_t, T_r) -- The storm depth selected for use with this methodology is associated with the 5-year event. The duration of the event should be matched to the duration (if any) of the water quality criterion (i.e., 24-hour LC_{50}). If no specific duration is associated with the criterion, then the user should attempt to maximize either the volume of runoff (for soluble pollutants) or sediment production (for adsorbed pollutants). Runoff volume is a function of storm depth. The storm depth, R_t, is a function of the storm duration chosen. For instance, the depth of the 5-year, 24-hour duration storm is greater than the depth of the 5-year, 0.5-hour duration event.

In this methodology, the storm that produces the greatest contaminant load is that which produces the greatest solids erosion load for contaminants with a high K_d. For low K_d values, the maximum runoff volume event is of greatest importance. Since there are no acute particulate related criteria, the methodology currently focuses on the dissolved portion of the contaminant load. In the case of high Kd values, storms that maximize the product Qq_p in Equation 6-18 maximize loadings at a given location. Because of the nonlinear relationships between curve number, storm duration and the product Qq_p in Equations 6-16 and 6-17, the storm duration that will produce the maximum Qq_p is not easy to select. For instance, at high curve numbers, short-duration storms tend to generate higher Qq_p products, and at low curve numbers, longer duration storms produce higher Qq_p products. Figure 6-4 illustrates this difficulty. For a 100-year recurrence interval at Jacksonville, Florida, using a curve

TABLE 6-4

Antecedent Rainfall Conditions and Curve Numbers*

Curve Number of Condition II	Factor to Convert Curve Number for Condition II to	
	Condition I	Condition III
10	0.40	2.22
20	0.45	1.85
30	0.50	1.67
40	0.55	1.50
50	0.62	1.40
60	0.67	1.30
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1.00	1.00

Condition	General Description	5-Day Antecedent Rainfall in Inches	
		Dormant Season	Growing Season
I	Optimum soil condition from about lower plastic limit to wilting point	<0.5	<1.4
II	Average value for annual floods	0.5-1.1	1.4-2.1
III	Heavy rainfall or light rainfall and low temperature within 5 days before the given storm	>1.1	>2.1

*Source: Schwab et al., 1966

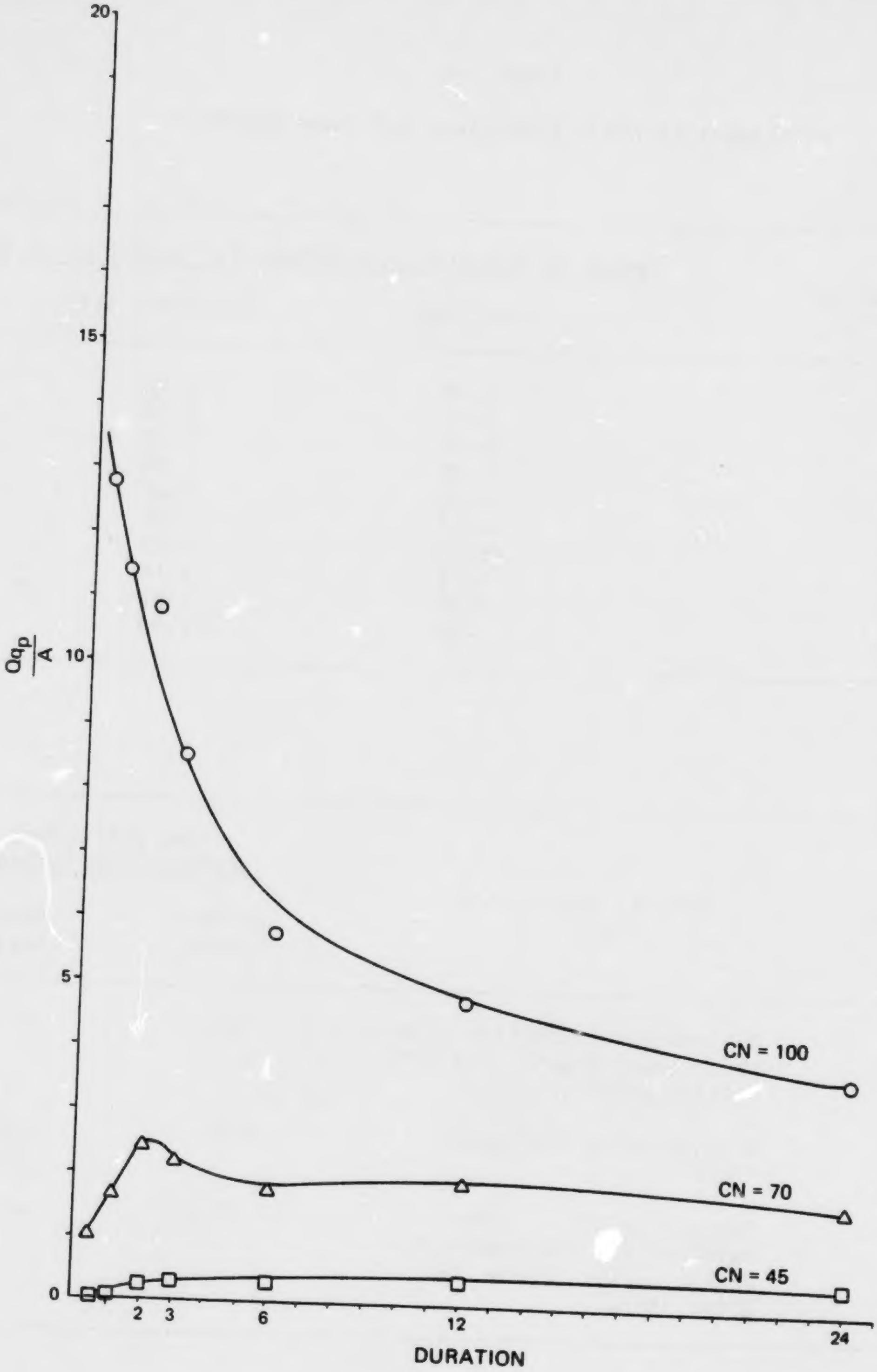


FIGURE 6-4

Erosion Potential for Storms of Various Durations for Soils With Selected Infiltration Properties number of 100, the shortest duration storm (0.5 hours) produces the highest erosion potential. At a curve number of 45, the longest duration storm (24 hours) produces the highest erosion potential, and at a curve number of 70, the 2-hour duration storm produces the highest potential.

The suggested approach is to run through the calculation of storm volume and peak runoff rate for each storm duration and select the storm having the greatest Qq_p product. Rainfall frequency maps, reproduced from Herschfield (1961) for the 5-year recurrence interval, are shown in Appendix 3.

6.4.1.5. AVAILABLE SOIL WATER -- Available water in the soil is defined as the difference between the water content at field capacity (θ_{fc}) and wetting point (θ_{wp}). Field capacity is a condition at which the forces that hold water in the soil are balanced by the force on the soil water that is due to gravity. This condition is usually taken to correspond to a tension in the soil of 0.33 bar. Wilting point is the water content at which the forces that hold water in the soil equal the force that plants can exert to extract it. This condition is usually taken to be at a tension of 15 bar.

Sludge additions to the soil increase the values of both θ_{fc} and θ_{wp}. Kladivco and Nelson (1979) and Gupta et al. (1977) reported that although θ_{fc} and θ_{wp} increased with sludge additions, the effect on their difference was negligible. Epstein et al. (1976) reported only a slight increase in available water. In their review of the available literature on the effects of organic waste applications on soils, Khaleel et al. (1981) concluded that the addition would have minor effects on available water. Therefore, no adjustment for available water for sludge additions is suggested.

To obtain a value for the soil(s) of interest, the data analysis done by Rawls et al. (1983) can be used. Figures 6-5 and 6-6, reproduced from their manuscript, give the water content at field capacity (1/3 bar) and wilting point (15 bar). The available water content is computed as the difference in these two. The textural classification of the soil (% sand, silt and clay) is needed to utilize the graphs. It can be estimated from Figure 6-7.

6.4.1.6. SOIL-WATER DISTRIBUTION COEFFICIENT OF CONTAMINANT (K_d) -- Soil-water partition coefficient may be determined from available information in the literature, may be estimated from other physicochemical properties or may be determined by site-specific experimentation. Guidance for determination of K_d is provided in Appendix 5.

6.4.2. Data Inputs for Receiving Water Analysis.

Only a single input parameter, the flow, is required for the receiving water calculation. However, derivation of the proper value depends on the analysis type (long-term or event) and the site location as discussed in the following.

6.4.2.1. LONG-TERM ANALYSIS -- For the long-term analysis, the receiving water is characterized by its total annual flow. This value is rarely reported for a water body. More typically, a mean annual flow rate will be given in m^3/sec or similar units. This value must be multiplied by the appropriate factor to convert it to volume/yr.

6.4.2.2. EVENT ANALYSIS - SITE ON SMALL STREAM -- For the event analysis, the total flow parameter is equated to the product of the flow and duration of the event. The duration of the flow event should match the duration of the rainfall event and the duration associated with the water quality criterion. The flow rate should be selected by finding the annual minimum flow rate of the proper duration that occurs once in 5 years. This is done by finding the minimum flow rate that occurs each year in a long-term data set of flow events. These annual minimum flow rates are then

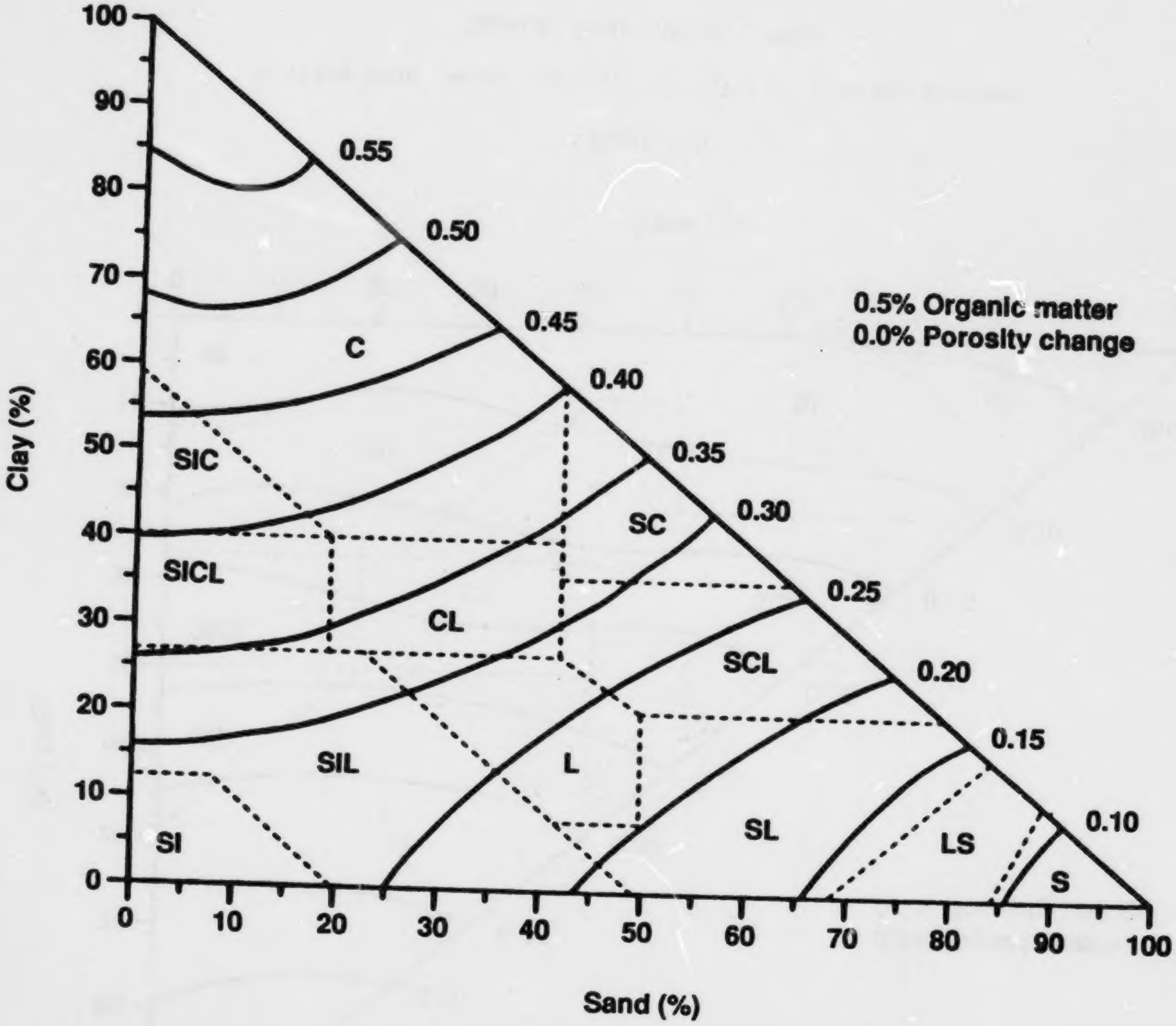


FIGURE 6-5

Field Capacity Water Content for Soils of Various Textures

Source: Rawls et al., 1983

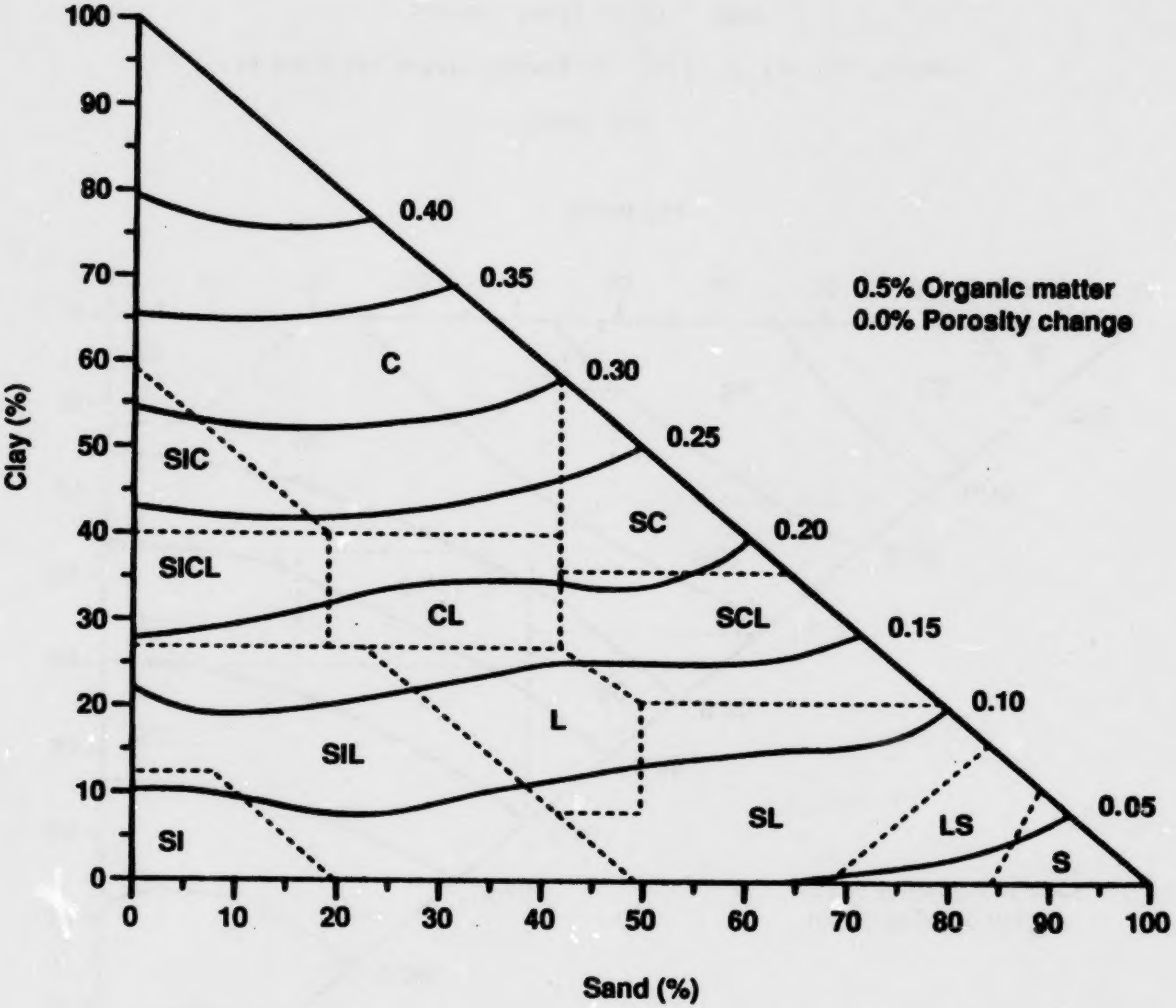


FIGURE 6-6

Wilting Point Water Content for Soils of Various Textures

Source: Rawls et al., 1983

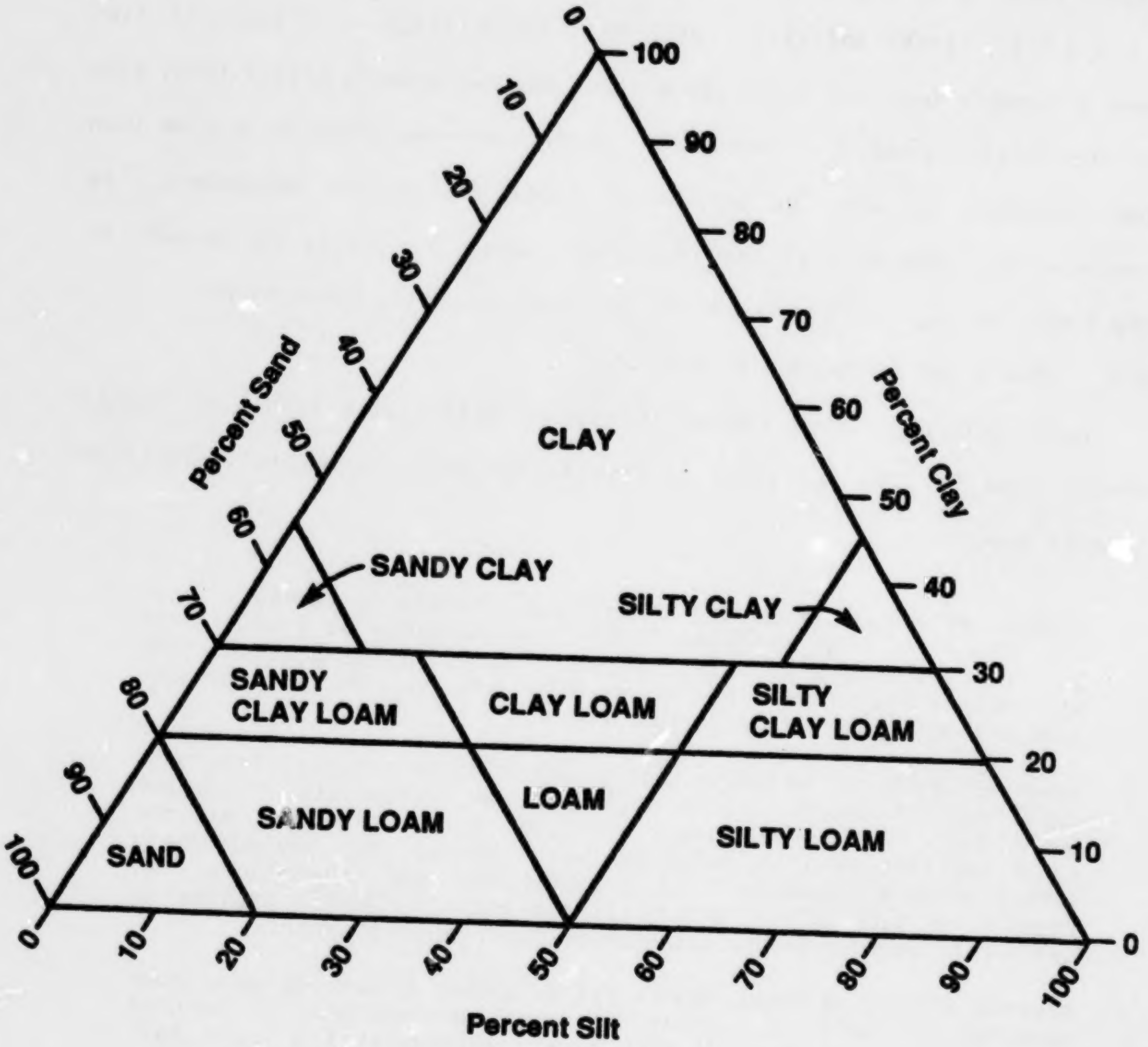

0
100
10
90
20
80
30
70
40
60
50
60
70
80
90
100
Percent Sand
Percent Clay
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Percent Silt
CLAY
SANDY CLAY
SILTY CLAY
SANDY CLAY LOAM
CLAY LOAM
SILTY CLAY LOAM
SAND
SANDY LOAM
LOAM
SILTY LOAM

FIGURE 6-7

Soil Classification Chart Developed by Bureau of Public Roads

Source: Terzaghi and Peck, 1967

ranked from smallest to largest and plotted on log-linear paper with flow on the arithmetic scale and recurrence interval on the log scale. The one in 5-year event is selected from a best-fit line through these points.

6.4.2.3. EVENT ANALYSIS - SITE ON A LARGE RIVER -- If the site lies near a large river, the local storm event may not greatly affect total flow in the receiving water. Indeed, the runoff event may occur at a time when the riverflow is very low because of conditions at the headwaters. To consider this possibility, the flow value should be set at the product of the 7-day, 10-year low flow rate and the duration of the storm event.

6.5. HEALTH AND ENVIRONMENTAL EFFECTS

Toxic pollutants that end up in surface waters as a result of surface runoff from the SMA can cause adverse health or environmental effects in several ways:

1. Adverse effects on fish and other biota inhabiting streams, lakes and estuaries. For example, if the concentration of a particular pollutant exceeds a certain reference value, fish and other biota will either die or experience some other adverse effects (reproductive effects, growth retardation, etc.).
2. Adverse effects on wildlife that consumes water and fish from polluted surface waters. Some pollutants may accumulate in surface water biota (bioaccumulation). Although these pollutants may not cause problems in fish and other water biota, they may adversely affect animals consuming such polluted fish and other biota. An example of such a possibility is the recent wildlife problem in California that is due to selenium-polluted surface waters.
3. Adverse effects on human health can be either direct, by water consumption, or indirect, by fish and animal consumption. If the diet includes fish and animals that have bioaccumulated a toxic pollutant from surface waters, the indirect mode of toxicant consumption may predominate.

The final RWC of a pollutant should be selected in a way that protects both the environment (fish and terrestrial wildlife) and human health.

6.5.1. Aquatic Life Protection. For protection of aquatic life from long-term effects, the AWQC should be used (Federal Register, 1980). The

AWQC contains two concentrations, one that should not be exceeded at any time and another that should not be exceeded, on an average, in a 24-hour period. Criteria for acute exposures normally utilize tests of 96-hour duration or less. For chemicals for which criteria are not available, the literature should be evaluated to determine whether useful data have become available since the AWQC was developed.

6.5.2. **Wildlife Protection.** Use of the AWQC is not sufficient for the protection of wildlife because it fails to account for biomagnification in the food chain. For certain chemicals, such as DDT with the biomagnification factor of up to 500,000 (Kenaga, 1972), the consumption of contaminated aquatic food may be a significant source of the residue body burden of members of higher trophic levels of the food chain. Moreover, the AWQC are designed for individual chemicals and do not account for interaction between chemicals.

6.5.3. **Human Health Effects.** RWC (in mg/ℓ) is defined as a surface water (stream, lake or estuary) concentration of pollutant used to evaluate the potential for adverse effects on human health. If a particular concentration in sludge or management practice of land application results in surface water concentration of a pollutant that is due to runoff greater than the RWC, adverse health effects may occur in a human population using the surface waters as a source of drinking water or consuming fish from these waters.

Two types of pollutants have to be considered: pollutants that act according to a threshold mechanism of toxicity and pollutants that act according to a nonthreshold mechanism.

6.5.3.1. **THRESHOLD-ACTING TOXICANTS** -- Threshold effects are those for which a safe (subthreshold) level of toxicant exposure can be defined.

The Agency considers that all noncarcinogenic toxicants act according to threshold mechanisms (Federal Register, 1980).

If the source of contaminant is only drinking water, RWC_w (mg/ℓ) is derived as follows:

$$RWC_w = \left(\frac{RfD \times bw}{RE} - TBI\right) \div I_w \qquad (6\text{-}39)$$

where:

RfD = reference dose (mg/kg/day)

bw = human body weight (kg)

I_w = total water ingestion rate (ℓ/day)

TBI = total background ingestion rate of pollutant (mg/day) from all other sources of exposure

RE = relative effectiveness of ingestion exposure

If the only source of pollutant is fish living in polluted surface waters, the reference concentration in water is calculated according to the following equation:

$$RWC_f = \left(\frac{RfD \times bw}{RE} - TBI\right) \div (BCF \times I_f) \qquad (6\text{-}40)$$

where:

BCF = bioconcentration factor in fish (ℓ/kg)
I_f = human consumption of fish (kg/day)

If the source of pollutant is both drinking water and fish from polluted surface water, the reference concentration is calculated according to Equation 6-41:

$$RWC_{wf} = \left(\frac{RfD \times bw}{RE} - TBI\right) \div [I_w + (BCF \times I_f)] \qquad (6\text{-}41)$$

The definition and derivation of each of the parameters used to estimate various RWCs for threshold-acting toxicants are further discussed below.

6.5.3.1.1. Reference Dose (RfD) -- When toxicant exposure is by ingestion, the threshold assumption has traditionally been used to establish an ADI. According to Lu (1983), the Food and Agricultural Organization and the World Health Organization have defined ADI as "the daily intake of a chemical that, during an entire lifetime, appears to be without appreciable risk on the basis of all the known facts at the time. It is expressed in milligrams of the chemical per kilogram of body weight (mg/kg bw/day)." Procedures for estimating the ADI from various types of toxicological data were outlined by the U.S. EPA in 1980 (Federal Register, 1980). More recently the Agency has preferred the use of a new term, the "reference dose," or RfD, to avoid the connotation of acceptability, which is often controversial.

Values of RfD for noncarcinogenic (or systemic) toxicity have been derived by several groups within the Agency. An effort is currently under way to corroborate these values and to produce a master list of RfDs for use by the various Agency programs. Most of the noncarcinogenic chemicals that currently are candidates for sludge criteria for the groundwater pathway are included on the Agency's RfD list, and thus no new effort will be required to establish RfDs for deriving sludge criteria. For any chemicals not listed, RfD values should be derived according to established Agency procedures (U.S. EPA, 1987).

6.5.3.1.2. Human Body Weight (bw) and Water Ingestion Rate (I_w) -- Both bw and I_w vary widely among individuals according to age and sex. For example, Table 6-5 shows the variation of adult drinking water intake within and among several studies. Mean intakes in New Zealand, Great Britain, The Netherlands and Canada varied from 0.96 to 1.30 ℓ/day, and 90th percentiles varied from 1.64 to 1.90 ℓ/day. The variations of mean drinking water intake and body weight with age and sex for the U.S. population are illustrated in Table 6-6. The choice of values for use in risk assessment depends on the definition of the individual at risk, which in turn depends on exposure and susceptibility to adverse effects. The RfD (or ADI) was defined above as the dose on a body-weight basis that could be

TABLE 6-5

Daily Intakes of Drinking Water by Adults[a]
(ℓ/day)

Mean±sd	Range	Percentiles				n	Method	Country	Reference
		10th	50th	90th	95th[b]				
1.25±0.39	0.26-2.80	0.42	1.26	1.90	2.2	109	Duplicate sampling	New Zealand	Gillies and Paulin, 1983
0.96±0.57	0.00-6.47	0.40	0.87	1.64	1.9	1960	24-hour recall	New Zealand	Birkbeck, 1977
1.08		0.50	--	1.68	1.9	2596	Diary	Great Britain	Hopkin and Ellis, 1980
1.26						1472		Netherlands	Hopkin and Ellis, 1980
1.30						342		Canada	Hopkin and Ellis, 1980

[a] Source: Gillies and Paulin, 1983

[b] Not reported in listed sources; estimated from log-probit plot of listed results.

TABLE 6-6

Water Ingestion and Body Weight by Age-Sex Group in the United States

Age-Sex Group	Mean Water Ingestion[a] (mℓ/day)	Median Body Weight (kg)	Water Ingestion per Body Weight (mℓ/kg/day)
6-11 months	308	8.8[b]	35.1
2 years	436	13.5[b]	32.2
14-16 years, female	587	51.3[b]	11.4
14-16 years, male	732	54.2[b]	13.5
25-30 years, female	896	58.5[c]	15.3
25-30 years, male	1050	67.6[c]	15.5
60-65 years, female	1157	67.6[c]	17.1
60-65 years, male	1232	73.9[c]	16.7

[a] Source: Pennington, 1983. From the revised FDA Total Diet Study. Includes categories 193, 195-197, 201-203.

[b] Source: Nelson et al., 1969. Calculated by averaging several age or sex groups.

[c] Source: Society of Actuaries, 1959. Average body weights for median heights of 156 cm (5 ft. 5 in.) and 173 cm (5 ft. 8 in.) for females and males, respectively.

safely tolerated over a lifetime. As shown in Table 6-6, water consumption on a body-weight basis is substantially higher for infants and toddlers than for teenagers or adults. Therefore, infants and toddlers would be at greater risk of exceeding an RfD when exposure is by drinking water. However, the effects on which the RfD is based may occur after a long cumulative exposure period, in some instances approaching the human lifespan. In these cases it may be reasonable to base the derivation of criteria upon adult values of bw and I_w. In cases where effects require a shorter exposure (i.e., <10 years) and where children are known to be at special risk, it may be more appropriate to use values for toddlers or infants.

The approach currently employed in the derivation of Recommended Maximum Contaminant Levels (RMCLs) by the U.S. EPA Office of Drinking Water is to assume a bw and I_w of 70 kg and 2.0 ℓ/day, respectively (Federal Register, 1985). As may be seen from Table 6-5, the value of 2.0 ℓ/day exceeds the 90th percentile estimates from the studies presented, and thus represents a relatively high exposure, although the total range can extend well above this value, at least on a given sampling day. On a body-weight basis, however, this represents an intake of 28.6 mℓ/kg/day, which is somewhat less than the mean intake for infants and toddlers. Therefore, care must be taken to ensure protection of children in cases where they are at risk. For example, the RMCL for lead, a toxicant known to threaten children, was based on exposure of infants rather than adults (Federal Register, 1985).

6.5.3.1.3. Total Background Ingestion Rate of Pollutant (TBI) -- It is important to recognize that sources of exposure other than the sludge disposal practice may exist, and that the total exposure should be maintained below the RfD. Other sources of exposure include background levels (whether natural or anthropogenic) in drinking water (other than groundwater), food and air. Other types of exposure that are due to occupation or habits, such as smoking, might also be included depending on data availability and regulatory policy. These exposures are summed to estimate the TBI.

Data for estimating background exposure usually are derived from analytical surveys of surface, ground or tap water; from FDA market basket surveys and from air-monitoring surveys. These surveys may report means, medians, percentiles or ranges, and detection limits. Estimates of TBI may be based on values representing central tendency or on upper-bound exposure situations, depending on regulatory policy. Data chosen to estimate TBI should be consistent with the value of bw. Where background data are reported in terms of a concentration in air or water, ingestion or inhalation rates applicable to adults or children can be used to estimate the proper daily background intake value. Where data are reported as total daily dietary intake for adults and similar values for children are unavailable, conversion to an intake for children may be required. Such a conversion could be estimated on the basis of relative total food intake or relative total caloric intake between adults and children.

As stated in the beginning of this subsection, the TBI is the summed estimate of all possible background exposures, except exposures resulting from a sludge disposal practice. To be more exact, the TBI should be a summed total of all toxicologically effective intakes from all nonsludge exposures. To determine the effective TBI, BI values for each exposure route must be divided by that route's particular RE factor. Thus, the TBI can be derived after all the background exposures have been determined, using the following equation:

$$\text{TBI (mg/day)} = \frac{\text{BI (food)}}{\text{RE (food)}} + \frac{\text{BI (nonsludge derived water)}}{\text{RE (water)}} + \frac{\text{BI (air)}}{\text{RE (air)}} + \ldots + \frac{\text{BI (n)}}{\text{RE (n)}} \quad (6\text{-}42)$$

where:

TBI = total background intake rate of pollutant from all other sources of exposure (mg/day)

BI = background intake of pollutant from a given exposure route, indicated by subscript (mg/day)

RE = relative effectiveness, with respect to drinking water exposure, of the exposure route indicated by subscript (unitless)

6.5.3.1.4. Relative Effectiveness of Exposure (RE) -- RE is a unitless factor that shows the relative toxicological effectiveness of an exposure by a given route when compared with another route. The value of RE may reflect observed or estimated differences in absorption between the inhalation and ingestion routes, which can then significantly influence the quantity of a chemical that reaches a particular target tissue, the length of time it takes to get there, and the degree and duration of the effect. The RE factor may also reflect differences in the occurrence of critical toxicological effects at the portal of entry. For example, carbon tetrachloride and chloroform were estimated to be 40 and 65% as effective, respectively, by inhalation as by ingestion based on high-dose absorption differences (U.S. EPA, 1984e,f). In addition to route differences, RE can also reflect differences in bioavailability due to the exposure conditions. For example, absorption of nickel ingested in water has been estimated to be 5 times that of nickel ingested in diet (U.S. EPA, 1985d). The presence of food in the gastrointestinal tract may delay absorption and reduce the availability of orally administered compounds, as demonstrated for halocarbons (NRC, 1986).

Physiologically based pharmacokinetic (PB-PK) models have evolved into particularly useful tools for predicting disposition differences due to exposure route differences. Their use is predicated on the premise that an effective (target-tissue) dose achieved by one route in a particular species is expected to be equally effective when achieved by another exposure route or in some other species. For example, the proper measure of target-tissue dose for a chemical with pharmacologic activity would be the tissue concentration divided by some measure of the receptor binding constant for that chemical. Such models account for fundamental physiologic and biochemical parameters such as blood flows, ventilatory parameters, metabolic capacities and renal clearance, tailored by the physicochemical and biochemical properties of the agent in question. The behavior of a substance administered by a different exposure route can be determined by adding equations that describe the nature of the new input function. Similarly, since known physiologic parameters are used, different species (e.g., humans vs. test species) can be modeled by replacing the appropriate constants. It should be emphasized that PB-PK models must be used in conjunction with toxicity and mechanistic studies to relate the effective dose associated with a certain level of risk for the test species and conditions to other scenarios. A detailed approach for the application of PB-PK models for derivation of the RE factor is beyond the scope of this document, but the reader is referred to the comprehensive discussion in NRC (1986). Other useful discussions on considerations necessary when extrapolating route-to-route are found in Pepelko and Withey (1985) and Clewell and Andersen (1985).

Since exposure for the runoff pathway is by drinking water or fish consumption, all the RE factors are applied with respect to the oral route. Therefore, the value of RE in Equations 6-39 to 6-41 gives the relative effectiveness of the exposure route and circumstances on which the RfD was based when compared with drinking water or food, as appropriate for each equation. Similarly, the RE factors in Equation 6-42 show the relative effectiveness, with respect to the oral route, of each background exposure route and matrix.

An RE factor should only be applied where well documented/referenced information is available on the contaminant's observed relative effectiveness or its pharmacokinetics. When such information is not available, RE is equal to 1.

6.5.3.1.5. Bioconcentration Factor (BCF) -- Bioconcentration is the ability of living organisms to accumulate substances to higher than ambient level concentrations. The degree to which a chemical accumulates in an aquatic organism above ambient concentrations is indicated by BCF. Specifically, it is defined as the quotient of the concentration of a substance in all or part of an aquatic organism (mg/kg fresh weight) divided by the concentration in water to which the organism has been exposed (mg/ℓ). The BCF is usually determined at equilibrium conditions, or for 28-day exposures, and is based upon the fresh weight of the organism. The BCF therefore has units of mg/kg $(\text{mg}/\ell)^{-1}$, or ℓ/kg.

Bioconcentration is distinguished from other terms commonly used to describe increases in the concentration of chemicals in an organism, such as biomagnification, bioaccumulation or ecological magnification, in that bioconcentration considers only the uptake of a pollutant by an organism from the ambient water. The other similar processes are associated with increases in the concentration of chemicals resulting from consumption of contaminated food sources as well as accumulation from water.

Although it has been documented in numerous studies that bioconcentration may be the primary pathway for accumulation (Marcelle and Thome, 1984; Bahner et al., 1977; Clayton et al., 1977), there is also evidence that biomagnification by aquatic food chains can be important under certain environmental circumstances (Lee et al., 1976).

Bioconcentration factors are specific for the compound and the species absorbing the compound. The compounds with the greatest tendency to bioaccumulate are those that are lipophilic and resistant to biological degradation. Initial diffusion into the organism occurs by rapid surface adsorption or partitioning to the lipoprotein layer of cell membranes. Once in the bloodstream, subsequent accumulation of the chemical into particular compartments of the organism is dependent upon the metabolic capabilities of the organism and the lipid content of the individual organs. With continuous exposure to a compound, the condition is eventually reached when the rate of excretion is equal to the rate of uptake.

Bioconcentration factors can be estimated through laboratory experiments, field studies, correlations with physicochemical factors such as octanol-water partition coefficients and models based upon pollutant biokinetics coupled to fish energetics. In the development of the ambient water quality criteria, the U.S. EPA used mostly laboratory data in the calculation of BCFs. Field data are often less reliable than laboratory data, because it cannot usually be shown that constituent concentrations in field situations have been held constant for a long period of time or over the range of territory inhabited by the organism. BCFs calculated from field data also may be greater than those calculated from laboratory data, which is apparently due to ingestion of the compound through prey, sediments and water in addition to absorption from water.

Where laboratory and field data are not available, bioconcentration factors can be estimated by several methods. Correlations between BCFs and octanol-water partition coefficients, water solubility and soil adsorption coefficients have been documented. Veith et al. (1979) developed the following equation using the correlation between the bioconcentration factor and the n-octanol/water partition coefficient (K_{ow}) to estimate BCFs to within 60% before laboratory testing:

$$\log_{10} \text{BCF} = 0.85 \log_{10} K_{ow} - 0.70. \qquad (6\text{-}43)$$

The equation was developed using data from whole-body analyses of ~7.6% lipids (Federal Register, 1980). The U.S. EPA adopted the equation developed by Veith et al. (1979) for use in determining BCFs for use in the exposure sections of the health effects chapter of the AWQC documents in those cases where an appropriate bioconcentration factor is not available. In a later study, Veith et al. (1980) used the results of their own laboratory experiments and data from other laboratories for a variety of fish species and 84 different organic chemicals to obtain the following modification of their original equation:

$$\log_{10} \text{BCF} = 0.76 \log_{10} K_{ow} - 0.23. \qquad (6\text{-}44)$$

Equations similar to the ones developed by Veith et al. (1979, 1980) have been developed for more specific chemical classes and particular aquatic species (Veith et al., 1979; Neeley et al., 1974). Other investigators (Norstrom et al., 1976) have developed more elaborate models using pollutant biokinetics and fish energetics in addition to using octanol/water partition coefficients to predict bioconcentration factors.

Since bioconcentration for lipophilic compounds depends on lipid content of the fish, it is important to adjust measured or estimated BCF values for these compounds to reflect the lipid content of seafood in the United States diet. The U.S. EPA determined in 1980 that the average lipid content of freshwater and estuarine species, weighted by average daily consumption, was 3.0% (Federal Register, 1980). Since fresh and estuarine waters would be those impacted by runoff from sludge application sites, a lipid content of 3.0% should be assumed. The adjustment is made as follows:

$$BCF_a = BCF_u \frac{LC_d}{LC_e} \qquad (6\text{-}45)$$

where:

BCF_a = adjusted BCF (ℓ/kg)
BCF_u = unadjusted BCF (ℓ/kg)
LC_d = lipid content of dietary seafood (kg/kg)
LC_e = lipid content of experimental organism (kg/kg)

6.5.3.1.6. Fish Consumption Rate (I_f) -- Several recent publications have provided estimates of average daily intake of fish. A USDA survey conducted in 1977-78 estimated mean intake to range from 9 to 14 g/day (including all types of fish such as shellfish and canned fish) depending on geographic region, with the Northeast showing the highest value (USDA, 1985). Another survey document estimated the national average to be 12.9 lb/year or 16 g/day (USDA, 1984). This latter document separates fish into categories, such as fish, shellfish, and canned fish. Daily intake of fresh or frozen fish was 6.46 g/day.

The most recent fish consumption document from the U.S. Department of Commerce (1985) reports total per capita fish and shellfish consumption ranging from 12.8 lb/year in 1980 to 13.6 lb/year in 1984, which is the highest consumption on record (Table 6-7). The latter value is a daily intake of 16.9 g of fish (all kinds). These figures do not include any recreational catch, which is estimated to be an additional 3-4 lb/year or 3.7-5 g/day (U.S. EPA, 1980a). If we assume a value of 3.5 lb/year or 4.35 g/day from recreational fishing, the total average per capita intake of all types of seafood is ~21.25 g/day.

Runoff from sludge disposal sites could affect freshwater and estuarine species, but not the marine species that constitute the greater portion of seafood in the U.S. diet. To estimate average daily consumption of the

TABLE 6-7

U.S. Annual Per Capita Consumption of Commercial Fish and Shellfish, 1960-1984[a]

Year	Civilian Resident Population	Per Capita Consumption			
		Fresh and Frozen[b]	Canned[c]	Cured	Total
	Million Persons	Pounds of Edible Meat			
1960	178.1	5.7	4.0	0.6	10.3
1961	181.1	5.9	4.3	0.5	10.7
1962	183.7	5.8	4.3	0.5	10.6
1963	186.5	5.8	4.4	0.5	10.7
1964	189.1	5.9	4.1	0.5	10.5
1965	191.6	6.0	4.3	0.5	10.8
1966	193.4	6.1	4.3	0.5	10.9
1967	195.3	5.8	4.3	0.5	10.6
1968	197.1	6.2	4.3	0.5	11.0
1969	199.1	6.6	4.2	0.4	11.2
1970	201.9	6.9	4.5	0.4	11.8
1971	204.9	6.7	4.3	0.5	11.5
1972	207.5	7.1	4.9	0.5	12.5
1973	209.6	7.4	5.0	0.4	12.8
1974	211.6	6.9	4.7	0.5	12.1
1975	213.8	7.5	4.3	0.4	12.2
1976	215.9	8.2	4.2	0.5	12.9
1977[d]	218.1	7.7	4.6	0.4	12.7

TABLE 6-7 (cont.)

Year	Civilian Resident Population	Per Capita Consumption			
		Fresh and Frozen[b]	Canned[c]	Cured	Total
	Million Persons	Pounds of Edible Meat			
1978[d]	220.5	8.1	5.0	0.3	13.4
1979[d]	223.0	7.8	4.8	0.4	13.0
1980[d]	225.6	8.0	4.5	0.3	12.8
1981[d]	227.7	7.8	4.8	0.3	12.9
1982[d]	229.9	7.7	4.3	0.3	12.3
1983[d]	232.0	8.0	4.8	0.3	13.1
1984[d]	234	8.3	5.0	0.3	13.6

[a] Source: Adapted from U.S. Department of Commerce, 1985

[b] Beginning in 1973, data include consumption of artificially cultivated catfish.

[c] Based on production reports, packer stocks and foreign trade statistics for individual years.

[d] Domestic landings data used in calculating these data are preliminary.

Note: These consumption figures refer only to consumption of fish and shellfish entering commercial channels, and they do not include data on consumption of recreationally caught fish and shellfish, which since 1970 is estimated to be between 3 and 4 pounds (edible meat)/person annually. The figures are calculated on the basis of raw edible meat (e.g., excluding bones, viscera, shells). The U.S. Department of Agriculture (USDA) consumption figures for red meats and poultry are based on the retail weight of the products, as purchased in retail stores. The USDA estimates are the net edible weight to be ~70-95% of the retail weight, depending on the cut and type of meat. From 1970 through 1980, data were revised to reflect the results of the 1980 census.

former, the U.S. EPA examined data from a survey of fish consumption in 1973-74 (as reanalyzed in U.S. EPA, 1980a) and eliminated all species not taken from fresh or estuarine waters (Stephan, 1980). Per capita consumption was reduced from 13.4 g/day to 6.5 g/day, or by a factor of 2.1. Therefore, it seems reasonable to assume that in most instances freshwater and estuarine species will constitute ~50% of total consumption or ~10.6 g/day.

There is a great disparity from the national average, depending on region, age, race and religion. SRI reported fish intake by the black and Jewish populations to be double the average value (U.S. EPA, 1980a). The New England and East South Central regions had the highest fish consumption regionally. Consumption levels in the upper 95th percentile were typically 300-400% of the national average. The highest value in the upper 95th percentile was for oriental populations at 67.3 g/day (Table 6-8). This is 502% of the national average reported by SRI. Applying the same percentage increase to the revised daily average consumption of 10.6 g/day, the 95th percentile is estimated to be ~53 g/day or ~43 lb/year.

6.5.3.2. CARCINOGENS -- For carcinogenic chemicals, the Agency considers the excess risk of cancer to be linearly related to dose (except at high-dose levels) (Federal Register, 1986a). Therefore, the threshold assumption does not hold, since risk diminishes with dose but does not become zero until dose becomes zero.

The decision of whether to treat a chemical as a threshold- or non-threshold-acting (i.e., carcinogenic) agent depends on the weight of the evidence that it may be carcinogenic to humans. Methods for classifying chemicals as to their weight of evidence have been described by the U.S. EPA (Federal Register, 1986a), and most of the chemicals that currently are candidates for sludge criteria have recently been classified in Health

TABLE 6-8

Fish Consumption by Demographic Variables (g/day)*

Demographic Category	Mean Consumption	Upper 95th Percentile
Race:		
Caucasian	14.2	41.2
Black	16.0	45.2
Oriental	21.0	67.3
Other	13.2	29.4
Sex:		
Female	13.2	38.4
Male	15.6	44.8
Age (years):		
0-9	6.2	16.5
10-19	10.1	26.8
20-29	14.5	38.3
30-39	15.8	42.9
40-49	17.4	48.1
50-59	20.9	53.4
60-69	21.7	55.4
70+	13.3	39.8
Census Region:		
New England	16.3	46.5
Middle Atlantic	16.2	47.8
East North Central	12.9	36.9
West North Central	12.0	35.2
South Atlantic	15.2	44.1
East South Central	13.0	38.4
West South Central	14.4	43.6
Mountain	12.1	32.1
Pacific	14.2	39.2

*Source: Adapted from U.S. EPA, 1980a

Assessment Documents or other reports prepared by the U.S. EPA's Office of Health and Environmental Assessment (OHEA), or in connection with the development of RMCLs for drinking water contaminants (Federal Register, 1985). To derive values of RWC, a decision must be made as to which classifications constitute sufficient evidence for basing a quantitative risk assessment on a presumption of carcinogenicity. Chemicals in classifications A and B, "human carcinogen" and "probable human carcinogen," respectively, have usually been assessed as carcinogens, whereas those in classifications D and E, "not classified" and "no evidence of carcinogenicity for humans," respectively, have usually been assessed according to threshold effects. Chemicals classified as C, "possible human carcinogen," have received varying treatment. For example, lindane, classified by the Carcinogen Assessment Group (CAG) of the U.S. EPA as "B2-C", or between the lower range of the B category and category C, has been assessed using both the linear model for tumorigenic effects (U.S. EPA, 1980b) and based on threshold effects (Federal Register, 1985).

In addition to the weight-of-evidence classification, which is independent of the exposure route, the route of exposure must also be considered. Certain compounds (e.g., nickel) have been determined to be probable or definite human carcinogens by the inhalation route but not by ingestion. The issue of whether or not to treat an agent as carcinogenic by ingestion remains controversial for several chemicals.

If a pollutant is to be assessed according to nonthreshold, carcinogenic effects, the reference concentration in surface water used for drinking, but not supplying fish for human consumption (RWC_w, in mg/ℓ), is calculated as follows:

$$RWC_w = \left(\frac{RL \times bw}{q_1^* \times RE} - TBI \right) \div I_w \qquad (6\text{-}46)$$

where:

q_1* = human cancer potency [(mg/kg/day)$^{-1}$]
RL = risk level (unitless)
bw = human body weight (kg)
I_w = water ingestion rate (ℓ/day)
RE = relative effectiveness of exposure (unitless)

If the only source of pollutant is fish from polluted surface waters, the reference concentration (RWC_f) is calculated according to the following:

$$RWC_f = \left(\frac{RL \times bw}{q_1^* \times RE} - TBI\right) \div (BCF \times I_f) \qquad (6\text{-}47)$$

If the sources of pollutant are both drinking water from surface waters and fish living in these surface waters, then the reference concentration (RWC_{wf}) can be calculated according to the following:

$$RWC_{wf} = \left(\frac{RL \times bw}{q_1^* \times RE} - TBI\right) \div [I_w + (BCF \times I_f)] \qquad (6\text{-}48)$$

where:

TBI = background ingestion rate of pollutant (mg/day) from all other sources of exposure

RE = relative effectiveness of exposure (unitless)

BCF = bioconcentration factor in fish (ℓ/kg)

I_w = water ingestion rate (ℓ/day)

I_f = human consumption of fish (kg/day)

q_1* = human cancer potency [(mg/kg/day)$^{-1}$]

RL = risk level (unitless)

TBI, RE, BCF, I_w and I_f are defined as for threshold-acting toxicants, and q_1* and RL are discussed in the next section.

6.5.3.2.1. Human Cancer Potency (q_1*) -- For most carcinogenic chemicals, the linearized multistage model is recommended for estimating human cancer potency from animal data (Federal Register, 1986a). When epidemiological data are available, potency is estimated based on the observed relative risk in exposed vs. nonexposed individuals, and on the magnitude of exposure. Guidelines for use of these procedures have been presented in the

Federal Register (1986a) and in each of a series of Health Assessment Documents prepared by OHEA (i.e., U.S. EPA, 1985c). The true potency value is considered unlikely to be above the upper-bound estimate of the slope of the dose-response curve in the low-dose range, and it is expressed in terms of risk-per-dose, where dose is in units of mg/kg/day. Thus, q_1* has units of $(mg/kg/day)^{-1}$. OHEA has derived potency estimates for each of the potentially carcinogenic chemicals that are currently candidates for sludge criteria. Therefore, no new effort will be required to develop potency estimates to derive sludge criteria.

6.5.3.2.2. Risk Level (RL) -- Since by definition no "safe" level exists for exposure to nonthreshold agents, values of RC are calculated to reflect various levels of cancer risk. If RL is set at zero, then RC will be zero. If RL is set at 10^{-6}, RC will be the concentration that, for lifetime exposure, is calculated to have an upper-bound cancer risk of 1 case in 1 million individuals exposed. This risk level refers to excess cancer risk, that is, over and above the background cancer risk in unexposed individuals. By varying RL, RC may be calculated for any level of risk in the low-dose region (i.e., $RL \leq 10^{-2}$). Specification of a given risk level on which to base regulations is a matter of policy. Therefore, it is common practice to derive criteria representing several levels of risk without specifying any level as "acceptable."

6.6. EXAMPLE CALCULATIONS

The methodology presented in the previous two sections can best be illustrated with example calculations. In this section, calculations are first made for an individual site as would be the case with a site-specific application. This site-specific forward calculation is made for both a long-term average loading case and an event loading case. An example is also given for development of national criteria for maximum allowable contaminant levels in sludge. In each case, both organic and inorganic contaminants are considered.

6.6.1. Site-Specific Application. A step-by-step discussion of a site-specific application to predict concentrations in runoff is presented below. The site is assumed to be a wooded area in the southeastern United States. The application addresses benzene as the constituent of interest. The input data to be used in this example application are presented in Table 6-9.

6.6.1.1. LONG-TERM AVERAGE LOADING --

I. For the Tier 1 analysis, calculate the maximum possible receiving water concentration using Equation 6-4:

$$C_i = \frac{Ni(A_s)(SMA)}{1000\ V}$$

where:

N_i = concentration of contaminant in sludge - 30 mg/kg benzene

A_s = sludge application rate - 220 mt/ha/3 yr = 73,333 kg/ha-yr

SMA = area of site to which sludge is applied - 100 ha

V = total annual flow - 1 m^3/sec x 31,536,000 sec/yr = $3.15\text{x}10^7$ m^3/yr

$$C_i = \frac{30\ (73{,}333)\ (100)}{(3.15\text{x}10^7) \times 10^3}$$

$$= 7.0\text{x}10^{-3}$$

C_i must then be compared to the reference water concentration, RWC. To derive RWC, it was assumed that the recieving water could serve as a source of both drinking water and fish consumption, and since benzene is a known human carcinogen, Equation 6-48 is used:

$$RWC_{wf} = \left[\frac{RL \times bw}{q1^* \times RE} - TBI\right] \div [I_w + (BCF \times I_f)]$$

TABLE 6-9

Input Parameters for the Example Calculations

Location -- Southeastern United States

Soil Type -- Silty clay loam

f_{oc} -- Organic Matter Content = 2%

Land Use -- Wooded, slight vegetative cover, poor hydrologic conditions

SMA -- SMA area, 100 ha

A_s -- Sludge application rate = 220 dry mt/ha/(3 years) = 73,000 kg/ha-yr

Δt -- Application elapse time, 30 years

R_c -- Recharge rate, 0.4 m/year

N -- Dry weight contaminant concentration in sludge, benzene = 30 mg/kg

B -- Sludge/soil bulk density, 1.2 g/cm^3

d -- Incorporation depth, 10 cm

L_b -- Buffer zone length, 100 m

W -- Buffer zone width, 1000 m

R_t -- Total event storm rainfall depth, 5 cm

M_t -- Total event snowmelt depth, 0 cm

T_r -- Storm duration, 6 hours

K_d -- Partition coefficient, benzene -- 7.4×10^{-3} cm^3/g

Q_f -- Mean streamflow, 1 m^3/sec

R_a -- Annual precipitation, 100 cm/year

---

where:

TBI = background ingestion rate of pollutant - set equal to zero in this example

RE = relative effectiveness of exposure - 1.0 is used since the cancer potency value is that for the ingestion route

BCF = bioconcentration factor = 5.2 ℓ/kg (U.S. EPA, 1980c)

I_w = water ingestion rate = 2 ℓ/day (see Section 6.5.3.1.2.)

I_f = human consumption of fish = 0.053 kg/day (see Section 6.5.3.1.6.)

q_1^* = 2.9×10^{-2} (mg/kg/day)$^{-1}$ (U.S. EPA, 1988)

RL = risk level - 10^{-6} used for purposes of example

$$RWC_{wf} = \left[\frac{10^{-6} \times 70}{0.029 \times 1} - 0\right] \div [2 + (5.2 \times 0.053)]$$

$$= 1.1 \times 10^{-3} \text{ mg/ℓ}$$

Since the value of Ci exceeds RWC, it is necessary to proceed to Tier 2/3.

II. For Tier 2/3, calculate the solids loading rate on erosion from the SMA using the USLE.

$$X_e = 2.24 \text{ R K (LS) C P} \tag{6-7}$$

A. Determine R: A value of R was selected from Figure A2-1. Values of R in the southeastern United States range from ~200 to 550 year^{-1}. In the interest of picking a reasonable "worst" case, a value of 400 year^{-1} was assumed for this example problem.

B. Calculate K: A "K" value of 0.32 tons/acre/year was selected from Table A2-2 for a silty clay loam soil with an organic matter content of 2%. Although the organic matter content may be higher in a sludge application area, this value was chosen to be conservative.

C. Calculate LS: An LS value of 4.33 was selected from Table A2-3 for a slope of 10% and a slope length of 1000 feet.

D. Determine C: A C value of 0.2 was assumed for a forested area with a slight vegetative cover.

E. Determine P: A P value of 1.0 was assumed since the land is non-agricultural and no managing practices are applied.

Based on the above values, and using Equation 6-7 the average annual sediment loss can be calculated as follows:

$$X_e = 2.24\ (400\ \text{year}^{-1})\ (0.32\ \text{tons/acre/year})\ (4.33)\ (0.2)\ (1.0)$$

$$= 248\ \text{metric tons/ha-year}$$

III. Calculate the contaminant concentration in in situ sludge and soil. Take into account zero-order and first-order loss rates of the contaminant from the soil.

For contaminants with first- and zero-order loss, Equation 6-8a is used.

$$M_m = \frac{k_2}{k_1}\left(1-e^{-k_1 \Delta t}\right) \qquad (6\text{-}8a)$$

A. Calculate the first-order coefficients for the composite loss rate (k_1) of benzene.

1. Calculate the first-order infiltration loss rate as the ratio of the recharge rate to the product of bulk density, depth of incorporation and the distribution coefficient.

$$k_{1i} = \frac{R_c}{(B\ d\ K_d)}\ (10^2) \qquad (6\text{-}8c)$$

$$= (0.4\ \text{m}^3/\text{m}^2\text{-year})(10^2/[(1.2\ \text{g/cm}^3)\ (10\ \text{cm})\ (7.4\times10^{-3}\ \text{cm}^3/\text{g})]$$

$$= 450\ \text{yr}^{-1}$$

2. Calculate the first-order surface runoff loss rate as the ratio of the sediment loss rate to the product of the bulk density and depth of incorporation.

$$k_{1R} = \frac{X_e}{B\ d}\ (10^{-2}) \qquad (6\text{-}8d)$$

$$= (10^{-2})\ (248\ \text{t/ha-yr})/[(1.2\ \text{g/cm}^3)\ (10\ \text{cm})]$$

$$= 0.2\ \text{yr}^{-1}$$

3. Calculate the first-order degradation loss rate.

$$k_{1D} = \lambda \qquad (6\text{-}8e)$$

$$= 3.9\ \text{yr}^{-1}$$

B. The composite first-order loss rate of benzene (k_1) is calculated from the sum of the three components.

$$k_1 = (k_{1i} = k_{1R} + k_{1D})$$

$$= (450 + 0.2 + 3.9)\ (\text{yr}^{-1})$$

$$= 454\ \text{yr}^{-1}$$

C. Calculate the benzene loading rate to the SMA (F_i) as the sludge application rate times the dry weight concentration of benzene in the sludge.

$$F_i = A_s\ N$$

$$= (73\ \text{t/ha-yr})\ (30\ \text{mg/kg})\ (1000\ \text{kg/t})$$

$$= 2.19\ \text{kg/ha-year}$$

D. Calculate the long-term maximum amount of benzene in the SMA.

$$M_m = \frac{k_2}{k_1}\ (1-e^{-k_1 \Delta t}) \qquad (6\text{-}8)$$

where $k_2 = F_i - k_o$

$= 2.19$ kg/ha-year - 0.0 kg/ha-year

$= 2.19$ kg/ha-year

$$M_m = \frac{2.19 \text{ kg/ha-year}}{454\text{/year)}} [1-e^{-(454/\text{year})(30 \text{ years})}]$$

$$= 4.8 \times 10^{-3} \text{ kg/ha}$$

E. Calculate the long-term maximum benzene concentration in the SMA by dividing the long-term maximum amount of benzene in the SMA (M_m) by the incorporation depth (d) times the sludge/soil bulk density (B).

$$C = 10\ M_m/(d\ B)$$

$$= \frac{(10)\ (4.8 \times 10^{-3} \text{ kg/ha})}{(10 \text{ cm})\ (0.8 \text{ g/cm}^3)} \qquad (6\text{-}10)$$

$$= 6.0 \times 10^{-3} \text{ mg/kg}$$

IV. Calculate the average annual loss of contaminant from erosion (L_o) as the average annual sediment loss (X_e) times the average contaminant concentration in the sludge/soil (C) times the area (SMA) of the SMA.

$$L_o = 10^{-3}\ X_e\ C\ (\text{SMA}) \qquad (6\text{-}11)$$

$$L_o = (10^{-3})\ (248 \text{ mt/ha-year})\ (6.0 \times 10^{-3} \text{ mg/kg})\ (100 \text{ ha})$$

$$= 0.15 \text{ kg/year}$$

V. Calculate the effect of the 100 m buffer zone on the average annual loss of contaminant from erosion (L_e). The average annual loss by contaminant would be scaled by the sediment delivery ratio (S_d), which is defined as

$$S_d = (3.28\ L_b)^{-0.22}$$

$$= [(3.28)(100)]^{-0.22} \qquad (6\text{-}12)$$

$$= 0.28$$

$$L_e = L_o\,S_d$$

$$= (0.15)(0.28) \qquad (6\text{-}13)$$

$$= 0.042 \text{ kg/year}$$

VI. Calculate the receiving water concentration as the ratio of total contaminant delivered each year to the total annual volumetric flow of the receiving water.

$$Ci = \frac{L_e}{1000\ V} = \frac{M_i}{1000\ V} \qquad (6\text{-}3)$$

$$= \frac{(2.2 \text{ kg/year})\ (10^6 \text{ mg/kg})}{(1 \text{ m}^3\text{/sec})\ (31{,}536{,}000 \text{ sec/year})\ (1000\ \ell/\text{m}^3)}$$

$$= 1.3 \times 10^{-6} \text{ mg}/\ell$$

This is well below the RWC of $1.1\text{x}10^{-3}$ mg/ℓ and indicates that no further long-term analysis is required.

6.6.1.2. EVENT LOADING --

I. Calculate the Tier I estimate of concentration for storm events using Equation 6-6.

A. Determine the total event mass loading. From Equation 6-5:

$$M_{i\ \text{event}} = N_i(A_s)(\text{SMA}) \qquad (6\text{-}5)$$

where:

M_i event = total event loading (mg)
N_i = total sludge contaminant concentration (mg/kg)
A_s = sludge application rate (kg/ha)
SMA = area of land to which sludge is applied (ha)

$$= (30 \text{ mg/kg})\ (73{,}333 \text{ kg/ha})\ (100 \text{ ha})$$

$$= 2.2\text{x}10^8 \text{ mg} = 220 \text{ kg}$$

B. Determine the concentration in the receiving water as the ratio of the event mass loading to the total receiving water flow during the storm event. From Equation 6-6:

$$C_j = \frac{M_{i\ \text{event}}}{1000\ V} = \frac{M_{i\ \text{event}}}{1000\ \ \ Qf(Tr)\ 3600}$$

where:

C_i = concentration of contaminant in receiving water (mg/ℓ)
M_i event = total mass loading from the storm event (mg)
1000 = concentration of m^3 to liters
Q_f = mean flow rate during storm event (m^3/sec)
T_r = duration of storm event (hours)
3600 = conversion of hours to seconds

$$= \frac{2.2 \times 10^8}{1000\ (1)(6)(3600)}$$

$$= 10 \text{ mg/ℓ}$$

This value would be compared with an acute RWC to determine its acceptability.

II. Calculate the runoff volume.

A. Calculate the watershed retention parameter (S) using the SCS runoff curve number (CN) of 77 (corresponds to a hydrologic soil Group C, a woods land use and poor hydrologic conditions). For condition AMC III, CN - 77(1.21) = 93 as indicated in Table 6-4.

$$S = 2.54\ [(1000/CN) - 10)]$$

$$= 2.54\ [(1000/93) - 10] \qquad (6\text{-}15)$$

$$= 1.91 \text{ cm}$$

B. Calculate the depth of runoff ($D_R Q$) from the watershed area as

$$D_R = \frac{(R_t + M_t - 0.2S)^2}{(R_t + M_t + 0.8S)} \qquad (6\text{-}14)$$

$$= \frac{[5 \text{ cm} + 0 \text{ cm} - (0.2)\ (1.91 \text{ cm})]^2}{[5 \text{ cm} + 0 \text{ cm} + (0.8)\ (1.91 \text{ cm})]}$$

$$= 3.27 \text{ cm}$$

C. Calculate the total storm runoff volume (Q) as the area (SMA) times the depth of runoff (D_R).

$$Q = 100\ (SMA)(D_R) \qquad (6\text{-}16)$$

$$= 3.3 \times 10^4 \text{ m}^3$$

III. Calculate the peak storm runoff (q_p) as

$$q_p = \frac{0.028\ (R_t + M_t) D_R}{T_r\ (R_t + M_t - 0.2S)} \qquad (6\text{-}17)$$

$$= \frac{(0.028 \text{ cm-hr/m-sec})\ (100 \text{ ha})\ (5 \text{ cm} + 0 \text{ cm})\ (3.27 \text{ cm})}{(6 \text{ hours})\ [5 \text{ cm} + 0 \text{ cm} - (0.2)\ (1.91 \text{ cm})]}$$

$$= 1.65 \text{ m}^3\text{/sec}$$

IV. Calculate the single-event sediment load as

$$X_e = 11.8\ (Q\ q_p)^{0.56}\ K\ LS\ C\ P \qquad (6\text{-}18)$$

where K, LS, C and P are defined in Appendix 2.

$$X_e = 11.8\ [(3.3\text{x}10^4 \text{ m}^3)(1.65 \text{ m}^3\text{/sec})]^{0.56} (0.32 \text{ tons/acre/yr})(4.33)\ (0.2)\ (1.0)$$

$$= 1468 \text{ metric tons}$$

V. Calculate the contaminant runoff loss.

A. Calculate the maximum contaminant level in the sludge (P_t) as follows:

$$P_t = \frac{k_2}{k_1} (1 - e^{-k_1 \Delta t})$$

$$= \frac{2.19 \text{ kg/ha-year}}{454\text{/year}} [1 - e^{-(454)\ (30 \text{ years})}]$$

$$= 0.8\text{x}10^{-3} \text{ kg/ha}$$

Divide by the incorporation depth, d.

$$P_a = \frac{4.8\text{x}10^{-3} \text{ kg/ha}}{10 \text{ cm}}$$

$$= 4.8\text{x}10^{-4} \text{ kg/ha-cm}$$

B. Calculate the available water capacity (θ) as the difference between the wilting point and field capacity water content.

From Figure 6-7 it can be determined that a silty clay loam soil has a textural classification of about 10% sand and 20% clay. From Figures 6-5 and 6-6 it can be determined that the water content at field capacity and wilting point are about 35 and 10%, respectively. The difference between these values yields an available water capacity of 25%. While these graphs are for 0.5% organics, both will change proportionally for 2% organics and, therefore, the 25% difference noted here is a good approximation for the same soil with 2% organics.

C. Calculate the adsorbed and dissolved fraction.

1. The adsorbed fraction is given by:

$$A_a = \left[\frac{1}{(1 + \theta/K_d\ B)}\right] P_a \qquad (6\text{-}24)$$

$$= \left[\frac{1}{[1 + 0.25/(7.4\times10^{-3}\ \mathrm{cm^3/g})\ (1.2\ \mathrm{g/cm^3})]}\right] 4.8\times10^{-4}\ \mathrm{kg/ha\text{-}cm}$$

$$= 16.5\ \mathrm{mg/ha\text{-}cm}$$

2. The dissolved fraction is calculated as follows:

$$D_a = \left[\frac{1}{(1 + K_d\ B/\theta)}\right] P_a \qquad (6\text{-}25)$$

$$= \left[\frac{1}{[1 + (7.4\times10^{-3}\ \mathrm{cm^3/g})\ (1.2\ \mathrm{g/cm^3})/0.25]}\right] 4.8\times10^{-4}\ \mathrm{kg/ha\text{-}cm}$$

$$= 464\ \mathrm{mg/ha\text{-}cm}$$

D. Calculate the loss of adsorbed and dissolved contaminant.

1. Adsorbed contaminant loss is calculated by:

$$P_{xt} = \frac{x_s}{100\ \mathrm{SMA}\ B} A_a\ (1\ \mathrm{cm}) \qquad (6\text{-}26)$$

$$P\,xt = \left[\frac{1468 \text{ mt}}{(100)\ (100 \text{ ha})\ (0.8 \text{ g/cm}^3)}\right] 16.5 \text{ mg/ha-cm}$$

$$= 3.0 \text{ mg/ha}$$

2. The dissolved contaminant loss is calculated as follows:

$$\left[P_{qt} = D_R/(R_t + M_t)\ D_a\right](1 \text{ cm}) \qquad (6\text{-}27)$$

$$= [3.27 \text{ cm}/(5 \text{ cm} + 0 \text{ cm})]\ 464 \text{ mg/ha-cm } (1 \text{ cm})$$

$$= 300 \text{ mg/ha}$$

V. Calculate the effect of the buffer strip on the event loading.

1. Calculate the sediment delivery ratio as follows:

$$S_d = (3.28\ L_b)^{-0.22} \qquad (6\text{-}12)$$

where:

L_b is the length of the buffer strip in m

$$=[(3.28)\ (100)]^{-0.22}$$

$$=0.28$$

2. Calculate the sediment load delivered to the receiving water as below:

$$P_{xt}' = [(X_e)(S_d)/(100)(SMA)B)]A_a \qquad (6\text{-}29)$$

$$= P_{xt}\ (S_d)$$

$$= (3.0 \text{ mg/ha})\ (0.28)$$

$$= 0.84 \text{ mg/ha}$$

3. Calculate the total unit area event dissolved contaminant loading to the receiving water.

$$P_{qt}' = P_{qt}$$

$$= 300 \text{ mg/ha}$$

4. Calculate total loads to the receiving water.

$$P_{qt}" = P_{qt}' \text{ (SMA)} \tag{6-30}$$

$$= 300 \text{ mg/ha (100 ha)}$$

$$= 3.0 \times 10^{4} \text{ mg}$$

$$P_{xt}" = P_{xt} \text{ (SMA)} \tag{6-31}$$

$$= (0.84 \text{ mg/ha}) (100 \text{ ha})$$

$$= 84 \text{ mg}$$

VI. Calculate the receiving water concentration for storm events using the dissolved contaminant loading.

$$C_i = \frac{P_{qt}"}{1000 \text{ V}} = \frac{M_{i \text{ event}}}{1000 \text{ V}} \tag{6-3}$$

$$= \frac{3.0 \times 10^{4} \text{ mg}}{1000 (\ell/\text{m}^3)(1 \text{ m}^3/\text{sec}) (6 \text{ hr}) (3600 \text{ sec/hr})}$$

$$= 1.4 \times 10^{-3} \text{ mg}/\ell$$

If acute sediment criteria were available, the concentration would be calculated as follows:

$$C_i = \frac{P_{xt}"}{1000 \text{ V}} = \frac{M_{i \text{ event}}}{1000 \text{ V}} \tag{6-3}$$

$$= \frac{84 \text{ mg}}{(1000 \ \ell/\text{m}^3)(1 \text{ m}^3/\text{sec})(6 \text{ hr}) (3600 \text{ sec/hr})}$$

$$= 3.9 \times 10^{-6} \text{ mg}/\ell$$

If the total event load were of interest

$$C_i = \frac{P_{xt}" + P_{qt}"}{1000(\ell/\text{m}^3)(1 \text{ m}^3/\text{sec})(6 \text{ hr})(3600 \text{ sec/hr})}$$

$$= \frac{84 \text{ mg} + 3 \times 10^{-4} \text{ mg}}{1000(\ell/\text{m}^3)(1 \text{ m}^3/\text{sec})(6 \text{ hr})(3600 \text{ sec/hr})}$$

$$= 1.4 \times 10^{-3} \text{ mg}/\ell$$

6.6.1.3. **EXAMPLE CALCULATIONS FOR SETTING NATIONAL CRITERIA** -- In this section, the surface runoff and receiving water body algorithms are used in reverse (as described in Section 6.3.2.4.) to determine the permissible contaminant concentration in runoff and sludge given an effects threshold value for the surface water body. For this example calculation, the benzene RWC value of 0.00067 mg/ℓ is applied. The Tier 2 methodology will be utilized throughout this section.

6.6.1.3.1. Case 1, Constant Loading --

From Section 6.3.3.3.

$$M_i = 1000V\ (RWC) = L_e \qquad (6\text{-}37)$$

$$= (1000\ \ell/m^2)\ (1\ m^3/sec)\ (31{,}560{,}000\ sec/year)\ (1.1\times10^{-3}\ mg/\ell)$$

$$= 3.5\times10^7\ mg/year = 35\ kg/year$$

Knowing the loading rate, M (from Section 6.3.3.1), the concentration in the solids may be solved by:

$$C = \frac{L_e\ (1000)}{X_e (SMA) S_d} \qquad (6\text{-}32)$$

where C is the solids concentration, X_e is the average annual sediment loss, SMA is the SMA area, and S_d is the sediment delivery ratio for the buffer strip.

Letting L_e = 35 kg/year

X_e = 248 metric tons/ha-year (from the forward calculation)

SMA = 100 ha

S_d = 0.28 (assuming 100-m buffer zone)
(from the forward calculation)

yields a solids concentration value of 5.0 (mg/kg).

Using equation 6-33, we may solve for the maximum contaminant mass M_m (kg/ha)

$$M_m = \frac{C\ d\ B}{10} \qquad (6\text{-}33)$$

where C is the solids concentration, d is the incorporation depth and B is the bulk density.

Letting $C = 5.0$ mg/kg

$d = 10$ cm

$B = 0.8$ g/cm^3

Yields $M_m = 4.0$ kg/ha

For degradable contaminants such as benzene,

$$M_m = \frac{k_2}{k_1}(1-e^{-k_1 \Delta t}) \qquad (6\text{-}8)$$

where:

$k_2 = F_1 - k_0$

$M_m = 4.0$ kg/ha

$\Delta t = 30$ years

$k_0 = 0$

$k_1 = k_{1i} + k_{1R} + k_{1D}$

$= 454$ yr^{-1} (see Section 6.6.1.1. example calculations steps IIIA and B)

Therefore:

$$M_m = (F_1)\ \frac{1}{k_1}(1-e^{-K_1 \Delta t})$$

or

$$F_1 = \frac{M_m}{\frac{1}{K_1}(1-e^{-K_1 \Delta t})}$$

$$= \frac{4.0 \text{ kg/ha}}{(1/454/\text{yr})\ [1-e^{-(454/\text{yr})(30 \text{ yr})}]}$$

$$= 1.8 \times 10^3 \text{ kg/ha-year}$$

Since the permissible dry sludge concentration is equal to the ratio of the limiting loading rate to the sludge application rate:

$$N_i = \frac{F_i}{A_s} \qquad (6\text{-}1)$$

$$N_i = \frac{1.8\text{x}10^{9}\ \text{mg/ha-year}}{73{,}000\ \text{kg/ha-year}}$$

$$= 2.5\text{x}10^{4}\ \text{mg/kg benzene in sludge}$$

6.6.1.3.2. Case 2 - Event Loading --

As noted in Section 6.3.4.2., receiving water concentrations are proportional to sludge levels for acute event analyses if only the dissolved contaminants are considered. Therefore, once a forward case has been run for a site, the limiting criteria can be determined from

$$N_{i\ \text{limiting}} = [(\text{RWC})/(C_i)]\ N_{i\ \text{test}}$$

where:

N_i limiting = the desired maximum concentration criteria level (mg/kg)

RWC = reference water concentration for acute exposure (mg/ℓ) -- in this example the Drinking Water Health Advisory for 10-day exposure of 0.235 mg/ℓ is used (U.S. EPA, 1988)

C_i = results of forward calculation for sludge with contaminant concentration Ni test - $1.4\text{x}10^{-3}$ mg/ℓ

N_i test = sludge contaminant concentration employed in the forward analysis of the site - 30 mg/kg

$$= [(0.235\ \text{mg/ℓ})/(1.4\text{x}10^{-3}\ \text{mg/ℓ})]\ 30\ \text{mg/kg}$$

$$= 5.0\text{x}10^{3}\ \text{mg/kg}$$

Hence, the scenario evaluated here will not exceed acute exposure criteria if sludge benzene levels are maintained below 5000 mg/kg. In this case, the long-term analysis generates the controlling sludge level of 25,000 mg/kg benzene compared with 5000 mg/kg for the event analysis.

7. CRITERIA CALCULATION METHODS FOR THE GROUNDWATER EXPOSURE PATHWAY

A risk assessment methodology for groundwater exposure resulting from the landfilling of municipal sludge has been developed as a part of this document series (U.S. EPA, 1986). The methods used to assess this pathway for land application and distribution and marketing (D&M) practices are identical to those for landfilling except for the "source term," that is, the calculations used to determine the amount and concentration of leachate initially generated at the soil surface. Therefore, this chapter will describe the source term in detail, but will refer to the Landfill Methodology Document to avoid lengthy repetition of the other portions. The example calculations given in Section 7.5. show the entire computation procedure for land application/D&M. The Landfill Methodology Document explains many of the terms and calculations used in Section 7.5.

7.1. OVERVIEW OF THE METHOD

It has been stated (see Section 3.4.) that the generation of leachate with subsequent migration to and contamination of groundwater is a pathway of potential concern. The approach for this pathway will be based on a methodology that can be applied directly to input data on a given site. The acceptability of a proposed land application or D&M practice can be weighed on the basis of predicted risks to human health through drinking water. A tiered approach is offered beginning with simple procedures and going to greater levels of sophistication only where necessary. The latter tiers allow introduction of site-specific values to reflect the conditions at the chosen site.

To implement such a methodology, it is necessary to simulate the movement of contaminants from the application area through the unsaturated soil column to the aquifer and then through the saturated zone laterally out from the site. The down-gradient property boundary may be selected as the point of compliance, since drinking water wells could be constructed from that point on and could then be affected by contamination with subsequent public health implications. Quantitative data on health effects, e.g., risk reference doses (RfD) for noncarcinogens or potency values (q_1*) for carcinogens, are used to determine a reference water concentration (RWC) for each chemical, which identifies the allowable level for groundwater contamination. The premise is that a potable water supply must be maintained at healthful levels for potential future uses even if there are no current uses immediately off site.

The tiered approach and the sequencing of the overall methodology are illustrated in Figure 7-1. The procedure begins with the analysis of total contaminant levels in sludge and conversion of bulk sludge application rates to contaminant mass addition rates on an annual basis. These mass rates are divided by the sum of annual recharge and drainage to generate average annual leachate concentrations for each contaminant. Predicted leachate concentrations for contaminants are compared with health criteria (RWC). Only those contaminants that exceed the health criteria will be considered for future evaluation. If no contaminants are predicted to be present in leachate above health criteria, Tier 1 is complete and no further analyses need be conducted.

A second or third tier analysis is required for each contaminant in the leachate at a level that exceeds the estimated health criterion (RWC) (fails Tier 1). The procedure is the same for both Tier 2 and Tier 3; the

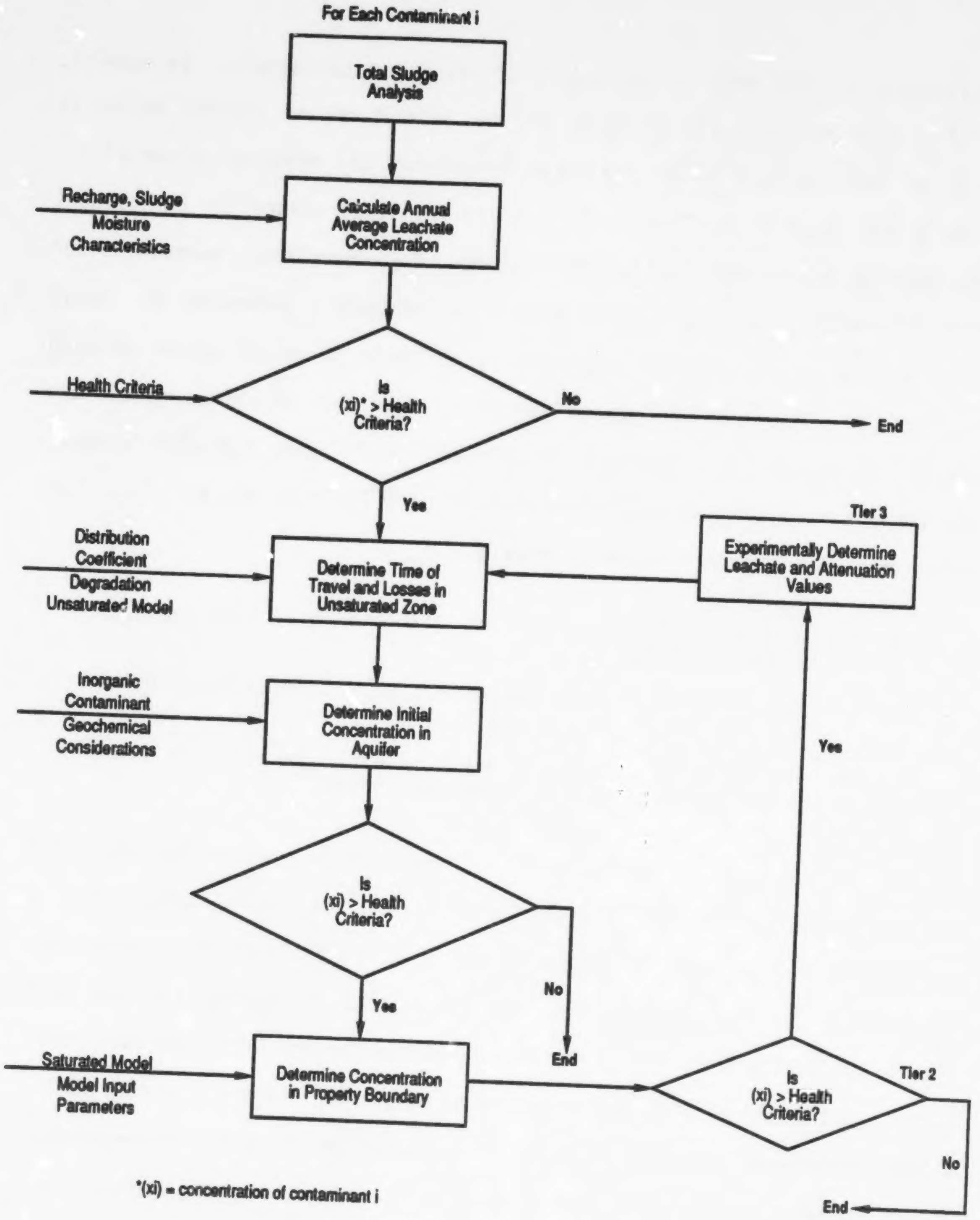

For Each Contaminant i
Total Sludge Analysis
Recharge, Sludge Moisture Characteristics
Calculate Annual Average Leachate Concentration
Health Criteria
Is (xi)* > Health Criteria?
No
End
Yes
Distribution Coefficient Degradation Unsaturated Model
Determine Time of Travel and Losses in Unsaturated Zone
Tier 3
Experimentally Determine Leachate and Attenuation Values
Inorganic Contaminant Geochemical Considerations
Determine Initial Concentration in Aquifer
Yes
Is (xi) > Health Criteria?
No
Yes
End
Saturated Model Model Input Parameters
Determine Concentration in Property Boundary
Is (xi) > Health Criteria?
Tier 2
No
End
*(xi) = concentration of contaminant i

FIGURE 7-1

Logic Flow for Groundwater Pathway Evaluation of Sludges Applied to Land difference between them is the source of the input parameters. In general, Tier 2 uses existing (those found in the literature) or generic values as well as some measured values, whereas Tier 3 uses all measured values (i.e., Tier 3 may be more specific). Tier 2 uses existing values for contaminant degradation rates, distribution coefficients, bulk densities, porosities and some unsaturated zone parameters (slope of the matric potential vs. moisture content curve). Actual measurements of these parameters would be used in Tier 3. Site-specific values should be used for all other parameters (depth to groundwater, distance to boundary, soil type, hydraulic conductivities, groundwater pH and Eh, etc.) in both Tiers 2 and 3. Thus, the three tiers can be described as follows:

Tier 1 -- Simple -- Compare predicted leachate concentrations with criteria (RWC).

Tier 2 -- More Complex -- Compare model results with criteria using existing or generic values as inputs.

Tier 3 -- Most Complex -- Compare model results with criteria using experimentally derived values as inputs.

The Tier 2/Tier 3 process also is initiated by calculating predicted leachate concentration for each contaminant. For degradable contaminants, a calculation is then made to determine how long it will take each contaminant to traverse the unsaturated zone, and the amount of degradation that will take place during that time. For nondegradable contaminants, the concentration is unchanged through the unsaturated zone. For inorganic contaminants, a speciation model (MINTEQ) is used to estimate the dissolved concentration of contaminants in the saturated zone after accounting for geochemical reactions.

At this point, after accounting for degradation and geochemical reactions, a comparison is made between predicted leachate concentration entering the aquifer and the RWC. The Tier 2/Tier 3 analysis is continued for those contaminants exceeding the RWC.

An analytical contaminant transport model, CHAIN, is used to predict contaminant concentration at the base of the unsaturated zone. The difference between the model and the unsaturated zone calculations discussed above is that the model allows for dispersion as well as degradation. For the metals (nondegradable), the output concentrations from the model are adjusted based on geochemical reactions (MINTEQ). At this point, the model-predicted or MINTEQ-adjusted contaminant concentrations at the base of the unsaturated zone (point of entry into the aquifer) are compared with the RWC. The Tier 2/Tier 3 analysis is continued for those that do not pass, i.e., concentration >RWC.

The final step of the Tier 2/Tier 3 analysis is to use a saturated zone transport model, AT123D, to predict contaminant concentration at the property boundary. These final contaminant concentrations at the property boundary are added to the background concentrations in the groundwater and again compared with the RWC. If they all pass, the application would be accepted. If any one contaminant exceeds the RWC, the application would be denied. If any contaminants exceed the RWC and the analysis has been completed through Tier 2, then a Tier 3 analysis can be performed using all site-specific data to see if all contaminant concentrations drop below the RWC. The procedures and details of each module in the methodology are described in the following sections.

7.2. ASSUMPTIONS

To apply a methodology such as that presented here, it is necessary to make simplifying assumptions. The assumptions, stated or implied, required to implement the groundwater pathway analysis methodology are outlined in Table 7-1.

7.3. CALCULATIONS

7.3.1. Source Term. Each contaminant transport pathway begins with a source term and ends with a receptor or point of exposure. In evaluating sludge disposal alternatives, the sludge itself is the source term through which the various contaminants are introduced to the environment. To quantify risks attendant to application of sludges to land, it is necessary to determine the mass of contaminant released as a function of time or as a concentration in the annual volume of leachate.

Because of economics and logistics, sludge application usually takes place as a limited number of discrete applications summing to the desired annual application rate as expressed in dry metric tons per hectare (Mg DW/ha). This and the periodicity of rainfall/snowmelt recharge events suggest the introduction of a finite number of contaminated leachate pulses into the groundwater system. In point of fact, however, travel in the unsaturated zone and dispersion in the aquifer act to integrate the pulses into a single leachate plume. This phenomenon, coupled with uncertainty surrounding the timing of recharge events each year, dictates the consideration of leachate volumes and contaminant masses in terms of average annual fluxes, that is, the volume/mass introduced each year.

On the surface, this annualizing affects the assessed hazard of a given scenario by reducing peak concentration estimates and extending the period of exposure. From a practical standpoint, the effects of the subsequent

TABLE 7-1

Assumptions for the Groundwater Pathway Methodology

Functional Area	Assumption	Ramifications
Source Term	After repeated sludge applications, yearly contaminant losses from soil/sludge zone will eventually equal yearly inputs. (Equilibrium maintained)	Overpredicts to the extent that some contaminants are irreversibly bound to solids or may react to become another chemical.
	Leachate pattern can be described as square wave.	Overpredicts duration of high concentration period, neglects presence of low concentration tail.
	Total Kjeldahl nitrogen (TKN) is completely converted to nitrate.	Overpredicts nitrate to the extent that some organic nitrogen may not readily break down.
Unsaturated Zone Transport	One-dimensional flow in the vertical direction.	Overpredicts concentration since it ignores horizontal dispersion.
	Water flow is steady state.	Overpredicts concentration by accelerating flow in a compressed time period.
	Water table conditions exist at bottom of unsaturated zone.	Does not affect concentration calculations.
	Upper boundary has a constant flux.	Overpredicts concentration by accelerating timeframe over which recharge actually occurs.
	Soil characteristics are constant with depth for any layer.	It is impossible to determine the effect of this assumption, since it will vary from site to site.

TABLE 7-1 (cont.)

Functional Area	Assumption	Ramifications
Unsaturated Zone Transport (continued)	Vertical hydraulic gradient of unity (not assumed in one of two alternative approaches).	Overpredicts concentration to the extent that gradients may be <1.0 and, therefore, time of travel is slower, allowing for more dispersion.
	Attenuation of organics is related to soil organic fraction only.	Overpredicts contaminant velocity for soils with low organic content where mineral interaction may predominate.
	All adsorption is reversible.	Overpredicts concentration arriving at aquifer.
	First-order degradation mechanism.	Underpredicts degradation where higher order rates are functional: overpredicts zero-order mechanisms.
Saturated Zone Transport	Dilution of leachate into aquifer is 100:1 with respect to complexants.	Underpredicts concentrations where stratification prevents complete mixing or where site constitutes major portion of recharge area.
	Groundwater conditions dictate geochemistry.	Effects would be site-specific depending on the quantity and quality of both the leachate and the aquifer.

TABLE 7-1 (cont.)

Functional Area	Assumption	Ramifications
Saturated Zone Transport (continued)	The six groundwater pH-Eh couplets modeled provide an adequate set of alternatives.	Some sites could have extreme conditions beyond those modeled. If pH values are very low, the model will underpredict, and if Eh conditions are very low the model will overpredict contaminant concentrations.
	Selected organics represent leachate component.	Since the high value for organic levels in leachate was selected, the potential complexants should overpredict mobility.
	Contaminant interactions do not affect geochemistry.	Effects would be source-specific.
	Degradation is by hydrolysis only and is first order.	May overpredict concentration where chemical or biological degradation can occur.
	No organic matter resides in aquifer media and, therefore, organics are not attenuated.	Overpredicts concentration by eliminating attenuation of organics.
	No contaminant is present in system to start with.	Underpredicts concentration if contaminant is present in native soils.
	Input concentration is constant.	Overpredicts concentration by equaling pulse to a square wave.

averaging are minimal since exposure is being evaluated in terms of dose over extended periods of time. For this type of exposure, the implications of ingesting 2 mg in a day are essentially the same as those for ingesting 1 mg for 2 days. As a result, the methodology requires an estimate of total mass of contaminant (flux) introduced to the system each year that it will then treat as a continuous pulse throughout the year. Since application will be repeated each year, the continuous annual pulses will, in effect, combine to form a steady-state flux of contaminant into the unsaturated zone. The mass flux is converted to a concentration by dividing it by the sum of recharge and sludge drainage. Therefore, source-term characterization must determine both the mass of available contaminant each year and the annual volumetric flow of leachate.

The annual mass flux of contaminant will depend on the total mass of contaminant in the sludge, the interactions between contaminant and sludge solids, and the volumetric flow of leachate. Concentrations in leachate may be dictated by partitioning phenomena or by solubility constraints. If partitioning is the controlling mechanism, contaminant concentrations in the soil/sludge zone at the surface will increase over the years until they reach a level that will sustain leachate concentrations that constitute a mass flux equal to the contaminant mass added in sludge each year, that is, losses equal inputs.

If solubility controls the leachate concentration, one of two situations may arise:

1. If solubility is high enough, leachate concentrations will be sufficient to transport in a year all of the contaminant added in a year; or
2. Lower solubilities will result in continued buildup of a contaminant inventory in the soil, which will sustain a continuous pulse at the solubility-constrained contamination.

In the first case, the result is the same as it would be if partitioning phenomena controlled leachate levels, that is, the average annual flux is equal to the mass of contaminant added in sludge each year. In the second case, the mass flux (and, therefore, concentration) would by definition be less than the mass of contaminant added in the sludge each year.

It is currently not possible to predict solubility levels for contaminants in the complex sludge and soil environment. Such data would have to be determined experimentally. As a consequence, Tier 1 and 2 analyses are based on the more conservative assumption that partitioning will result in contaminant mass fluxes to groundwater equivalent to the mass of contaminant applied. In Tier 3, the applicant can spike sludges with increasing levels of contaminant to determine maximum solubility levels in leachate as discussed at the end of this section.

For Tiers 1 and 2, it is necessary first to quantify the mass flux for each contaminant and then to convert it to the equivalent concentration for a continuous pulse. The first step is to analyze the sludge and determine the concentration (SC_i) for each contaminant i in terms of mg contaminant per kg of dry sludge solids. For nondegrading contaminants, this value can then be converted to the desired annual flux (F_i) according to this equation:

$$F_i = (SC_i)(A_s) \qquad (7\text{-}1a)$$

where:

F_i = mass flux for i (mg/m²-yr)

SC_i = concentration of i in sludge (mg/kg)

A_s = annual application rate for sludge (kg sludge/m²-yr). (For sludge uses where application is made in multiples of years rather than annually, A_s is calculated as the ratio of actual application rate to the period of years between applications. Note that A_s has different units than the rate AR used in Chapter 4.)

For degradable contaminants, losses are equated to the total of leachate-transported contaminant and degradation. Therefore,

$$F_i = (A_s)(SC_i/k)[1-e^{-k}] \qquad (7\text{-}1b)$$

where:

k = the degradation rate constant (yr-1)

In this equation, $(SC_i/k)[1-e^{-k}]$ would represent the average sludge concentration during a 1-year period. Generally the form would be $(SC_i/kt)[1-e^{-kt}]$, but for this case, $t = 1$. To convert F_i to the leachate concentration X_i, it is necessary to calculate the volume of leachate generated each year.

Leachate will arise from three sources: natural recharge (rainfall and snowmelt, which percolates into the ground), irrigation and drainage water from the applied sludge. Recharge (R) is calculated as total precipitation (P) less runoff (RO) and evapotranspiration (ET).

$$R = P - RO - ET \qquad (7\text{-}2)$$

Recharge may be reported for a given area or may be calculated from estimates of P, RO and ET. Irrigation (IR) data are taken directly from site operating conditions.

Drainage from the sludge is calculated as the difference between the initial moisture content and the sludge and its storage capacity for water. Drainage volume is calculated according to the following equation:

$$D_v = (L - S)\left[\frac{0.001\ A_s}{(1 - L)(1 - S)}\right] \qquad (7\text{-}3)$$

where:

D_v = drainage volume in m^3 water/m^2-yr

L = initial moisture content of sludge (kg/kg)

S = storage capacity of sludge (kg/kg)

A_s = annual sludge application rate in kg/m^2-yr

0.001 = inverse of the density of water (m^3/kg)

The equivalent concentration of leachate moving in a continuous pulse is defined in the following equation:

$$X_i = \frac{0.001\ F_i}{R + IR + D_v} \tag{7-4}$$

where:

F_i = mass flux derived from Equation 7-1a or 7-1b (mg/m^2-yr)

R = recharge in m^3/m^2-yr

IR = irrigation in m^3/m^2-yr

D_v = drainage volume in m^3/m^2-yr

The 0.001 converts concentrations from mg/m^3 to mg/ℓ.

In Tier 1 analysis, the predicted leachate concentration, X_i, is compared with the health criterion (reference water concentration, RWC) for each contaminant. If the criterion is not exceeded, the contaminant can be dropped from further evaluation in the groundwater pathway. If the criterion is exceeded, the analysis proceeds to Tier 2. In Tier 2, the predicted leachate concentration, X_i, is used as the input for the unsaturated zone portion of the methodology.

As indicated earlier, the methodology is conservative in defining X_i. If an applicant believes that such conservatism is excessive, a Tier 3 approach can be taken. Tier 3 allows for the determination of X_i experimentally. In this case, the sludge is subjected to the Toxicity Characteristic Leachate Procedure (TCLP) as described in Appendix A of the Landfill Methodology Document (U.S. EPA, 1986). [If sludge is to be incorporated in the soil, a combined sample of site soil and sludge in the proper ratio should be subjected to the TCLP.] The resulting leachate concentration from the TCLP is compared with the predicted leachate value. If the TCLP leachate concentration exceeds the predicted leachate concentration, then solubility constraints will not control the annual flux of contaminant, and the predicted leachate concentration is the proper input value for the methodology. If the TCLP concentration is less than the predicted leachate concentration, solubility limitations may control the mass flux and further analysis is warranted.

If solubility is the controlling factor, the concentration of a contaminant in the leachate should not change in response to changes in the concentration of contaminant in the total sludge. When leachate concentration does increase with sludge contaminant levels, a partitioning phenomenon is more likely. To determine which is the case, it is necessary to perform the TCLP on sludges with two different contaminant concentrations: one equivalent to that of the average sludge and one spiked to a higher level (a multiple of 4) analagous to the buildup of contaminant in the soil when annual losses do not equal inputs. If the TCLP results do not show a significant difference between the two samples, solubility would appear to be the controlling mechanism and the TCLP concentration should be applied as input to the methodology. If the spiked sludge yields a commensurately higher concentration, partitioning would appear to control leachate levels, and the predicted leachate concentration from Equation 7-4 is the proper starting point for the methodology.

The TCLP uses a 20:1 ratio of extracting solution to sludge. This may not represent actual ratios of water to sludge. The water level was selected for ease of operation of the test and to assure good contact with agitation. At a land application site, sludge moisture content will fluctuate with infiltration levels. After precipitation events, sludge will adsorb moisture up to its storage capacity, that is, the equilibrium moisture content after drainage. As more water is introduced, it will force water through the sludge and increase the volume of leachate. During dry periods, the sludge will drain to its storage capacity. At that point, further water loss will result from capillary movement of water into surrounding soils and evaporation. On the average, the sludge would contact water ratios at or below the level represented by the storage capacity. Values for water content of drained sludges are given in Table 7-2. From these data it would appear that sludges will maintain water-to-solids ratios in the range of 6 to 66 depending on their origin. Most sludges retain water at a ratio in the range of 12:1 to 24:1. This is similar to the 20:1 ratio employed in the TCLP and, hence, leachate concentration values taken directly from the TCLP can be considered representative without further calculation.

In addition to toxic contaminants, nitrate is a limiting constituent for sludge disposal on land. Nitrate is highly soluble and will not remain at high levels in sludge. However, organic nitrogen measured as total Kjeldahl nitrogen (TKN) degrades to nitrate over time. Therefore, leachate from the TCLP will be analyzed for TKN in addition to prescribed toxic contaminants.

These formulations assume all contaminants in a sludge are ultimately mobile and that contaminant concentrations remain relatively constant in leachate until the total mass is virtually depleted. The first assumption is conservative in that it does not subtract the nonmobile fractions of contaminant. If the applicant can demonstrate that the total available mass of contaminant (Ma) is statistically significantly less than the total mass, M, then $[(Ma/M)(SC_i)]$ may be inserted for SC_i in Equation 7-1a or 7-1b for Tier 2. Thus, if $Ma < M$ then

$$F_i = [(Ma/M)\ (SC_i)]\ (A_s) \text{ for nondegrading contaminants}$$

$$\text{and } F_i = (A_s)\ [(Ma/M)\ (SC_i)]/k \quad [1-e^{-k}] \text{ for degrading contaminants}$$

In summary, source term characterization consists of first defining the mass flux of contaminant into the unsaturated zone and then converting it to a leachate concentration.

TABLE 7-2

Water Content of Sludges from Various Treatment Processes*

Sludge Type	Water Content (%)	Water-to-Solids Ratio
Primary sludge	95	19
Digested primary sludge	94	16
Trickling filter	92	12
Chemical precipitation	92	12
Primary and activated sludge	96	24
Digested primary and activated sludge	94	16
Activated sludge	98.5	66
Septic tank-digested activated sludge	90	9
Imhoff tank-digested activated sludge	85	6

*Source: U.S. EPA, 1978

7.3.2. Unsaturated Zone Transport. As leachate is generated at the land application site, it moves vertically downward through the unsaturated zone to the uppermost aquifer. To measure the risk to water quality by contaminants in the leachate, it is necessary to determine the time of travel required to reach the aquifer and subsequent effects on contaminant concentrations. Refer to Section 4.3.2. of the Landfill Methodology Document (U.S. EPA, 1989) for unsaturated zone transport methods.

7.3.3. Saturated Zone Transport. Methods for calculating saturated zone transport are given in Section 4.3.3. of the Landfill Methodology Document (U.S. EPA, 1989). Methods for land application do not differ except that contaminant input is assumed to be continuous rather than a finite pulse, as in the landfill methodology. Therefore, pulse duration is not calculated for land application. The output of the saturated zone transport calculation is contaminant concentration as a function of time at the down-gradient compliance point.

7.3.4. Setting National Criteria. The methodology presented herein has been devised to evaluate the land application of municipal sludge on a site-specific basis. As mentioned previously, it can also be employed to establish sludge content criteria to be administered on a national or regional scale. For this purpose, the mode of operation is, theoretically, the reverse of that presented in earlier portions of this section. That is, the analysis begins with the selected effects threshold level and works backward to determine how high a concentration in the sludge it would take for environmental levels to exceed that threshold. Hence, the analysis begins with the point of compliance, moves back through the aquifer to the point below the disposal facility, and then moves up through the unsaturated zone to the surface and the sludge itself.

Functionally, the reverse operation is not so straightforward. Some of the models and constructs employed in the methodology cannot be operated in the reverse mode, that is, the analytical model is not closed form so one cannot set the final concentration and solve for the initial concentration. Therefore, it is necessary to deal with each element of the methodology individually to meet the needs of the criteria-setting mode of operation.

Transport in the saturated zone is the first element that must be considered when operating the criteria-setting mode. Since the analytical constructs employed are not of a closed form, this is one of the elements of the methodology that cannot simply be operated in the reverse. The analytical models recommended, including AT123D, provide a linear response between input loading and output concentration at a given downgradient distance. Therefore, a given set of site characteristics will produce a unique value of C/q_o, where C is the final concentration and q_o is the mass flux input. The mass flux can be converted from the unsaturated concentration X as

$$q_o = X\ (R + IR + D_v) \qquad (7\text{-}5)$$

where:

R = recharge, IR = irrigation, and D_v = drainage volume, all in m^3/m^2-yr. Thus, for any given set of site parameters, the input concentration can be calculated as a direct multiple of the output concentration. Having determined C/q_o for a site, one can equate C to the RWC for the chemical of interest and obtain the necessary reference starting concentration, RC, where the leachate enters the aquifer, as

$$RC = RWC\ \left(\frac{q_o}{C}\right)\ \left(\frac{1}{R + IR + D_v}\right) \qquad (7\text{-}6)$$

The above use of the model results will yield a reference starting aquifer concentration, RC, that will just produce the effects threshold at the point of interest. This analysis accounts for the effects of dispersion and degradation in the aquifer. Attenuation effects are also accounted for but are not of concern because they influence only the timing, and not the magnitude of the effects.

As described earlier, for inorganic contaminants it is assumed that geochemical effects on contaminant concentration occur as the leachate enters the aquifer. Therefore, the MINTEQ results from the saturated zone transport method can be used to further scale the reference starting aquifer concentration, RC.

In the case of the nondegradable inorganics (such as arsenic, copper, lead, mercury and nickel), the acceptable concentration leaving the unsaturated zone is determined by locating RC on the vertical axis of the graph of MINTEQ results (saturated zone concentration) and reading the corresponding unsaturated zone concentration from the horizontal axis (see Figure 4-3 of the Landfill Methodology Document; U.S. EPA, 1986). The resulting value should be used to replace RC. If the saturated zone reading does not fall on the curve, then solubility constraints will prevent the health effects threshold from being exceeded, and no sludge criteria are required.

The above analysis yields acceptable levels of contaminants in leachate just entering the aquifer. These acceptable concentrations can be related to acceptable levels in leachate leaving the site through use of the CHAIN unsaturated transport code. The CHAIN code generates a concentration in the form C/Co. Therefore, the reference starting leachate concentration, RX, can be found from a CHAIN run for a given site as

$$RX = RC\ (Co/C) \qquad (7\text{-}7)$$

The value RX is then the maximum allowable predicted or measured concentration of contaminant in the leachate.

7.4. INPUT PARAMETER REQUIREMENTS

A number of inputs are required to apply the groundwater pathway calculation methods. Most of these are as discussed in Section 4.4. of the Landfill Methodology Document (U.S. EPA, 1986). A few inputs that define the source term and are unique to the land application methodology are described as follows.

7.4.1. Fate and Transport: Pathway Data.

7.4.1.1. TOTAL RECHARGE (R + IR) -- Obtained from local weather station data or agricultural extension offices as the sum of natural recharge and irrigation less evapotranspiration.

7.4.1.2. ANNUAL SLUDGE APPLICATION RATE (A_s) -- Taken from assumed or actual operating procedures.

7.5. EXAMPLE CALCULATIONS

The methodology presented in the previous sections can best be illustrated with an example calculation. In the following, calculations are first made for an individual site as would be the case with a site-specific application. Then an example is given for development of criteria for maximum allowable contaminant levels in sludge. To best illustrate this methodology, the example considers an organic contaminant. Input parameters for the example calculations are provided in Table 7-3.

7.5.1. Site-Specific Application.

A step-by-step discussion of a site-specific application follows. The application uses hexachlorobenzene as the constituent of interest.

The RWC for the carcinogen hexachlorobenzene is derived using Equation 4-33 from the Landfill Methodology Document (U.S. EPA, 1986), also given as Equation 6-46 of this report:

$$\text{RWC} = \left[\left(\frac{\text{RL} \times \text{bw}}{q_1^* \times \text{RE}}\right) - \text{TBI}\right] \div I_w \qquad (7\text{-}8)$$

TABLE 7-3

Input Parameters for Example Calculations - Groundwater

Fate and Transport: Pathway Data	
Source Term	
1. Water Content of Sludge	$WS = 0.95$ kg/kg
2. Storage Capacity of Sludge	$S = 0.90$ kg/kg
3. Net Recharge	$R + IR = 0.5$ m/year
4. Annual Sludge Application Rate	$A_S = 50$ Mg DW/ha-year $= 5$ kg/m^2-year
Unsaturated Zone	
5. Depth to Groundwater	$hy = 1$ m
6. Distance to Property Boundary	$ds = 100$ m
7. Material	Sandy Loam
8. Thickness	$m = 1$ m
9. Saturated Soil Hydraulic Conductivity	$k_{sat} = 10^4$ m/year
10. Slope of Matric Potential and Moisture Content Plot	$b = 4.0$
11. Saturated Soil Moisture Content	$f_s = 0.39$ m^3/m^3
12. Bulk Density	$B_u = 1400$ kg/m^3
Saturated Zone	
13. Groundwater	$pH = 6$
14. Groundwater	$Eh = 150$ mvolts
15. Hydraulic Conductivity	$K = 1.5 \times 10^5$ m/yr
16. Effective Porosity	$\theta_e = 0.10$
17. Hydraulic Gradient	$(\partial H/\partial X) = 0.003$

TABLE 7-3 (cont.)

Fate and Transport: Pathway Data -- Saturated Zone (cont.)	
18. Bulk Density	B_s = 2390 kg/m^3
19. Dispersion Coefficient	$D_x = 4.5 \times 10^4$ m^2/year $D_y = 4.5 \times 10^3$ m^2/year $D_z = 4.5 \times 10^3$ m^2/year
20. Site Geometry Site width Site length	 SW = 10^3 m SL = 10^3 m
Fate and Transport: Chemical-Specific Data	
Source Term	
21. Hexachlorobenzene concentration in sludge	SC = 2.2 mg/kg
Unsaturated Zone	
22. Hexachlorobenzene soil distribution coefficient	K_d = 0.4 ℓ/kg
23. Hexachlorobenzene degradation rate constant	k = 0.16 $year^{-1}$
Saturated Zone	
24. Hexachlorobenzene soil distribution coefficient	K_d = 0.0 ℓ/kg
25. Hexachlorobenzene degradation rate constant	k = 0.0 $year^{-1}$
Chemical-Specific Data -- Health or Environmental Effects	
26. Hexachlorobenzene reference water concentration	RWC = 0.000021 mg/ℓ

The risk level (RL), the body weight (bw) and the daily ingestion rate (I_w) are set for this example at 10^{-6}, 70 kg and 2 ℓ, respectively. The relative effectiveness factor (RE) is set at 1. The human cancer potency for hexachlorobenzene has been determined by the U.S. EPA to be 1.7 $(mg/kg/day)^{-1}$ (Federal Register, 1985). Current total background intake (TBI) of hexachlorobenzene from all other sources (other than sludge land application practices) has not been determined, but for illustrative purposes a TBI of 0 is used here to derive an example RWC. Determination of an RWC for a specific site should be based on a current local assessment of TBI.

$$RWC = \frac{10^{-6} \times 70 \text{ kg}}{1.7 \text{ (mg/kg/day)}^{-1}} - 0 \div (2 \ \ell)$$

$$= 2.11 \times 10^{-5} \text{ mg}/\ell$$

$$= 0.021 \ \mu g/\ell$$

7.5.1.1. TIER 1 --

A. Calculate the flux, or annual mass of contaminant, added per m^2 of site (F_i). For degradable contaminants, the flux is calculated as follows from Equation 7-1b:

$$F_i = (A_s)(SC_i/k)[1-e^{-k}] \qquad (7\text{-}9)$$

where:

A_s = annual application rate of sludge (kg DW/m^2-year)

SC_i = sludge concentration of contaminant i (μg/g DW)

k = degradation rate constant ($year^{-1}$)

e = base of natural logarithms, 2.7183 (unitless)

F_i = (5 kg/m^2-year)(2.2 μg/g ÷ 0.16 $year^{-1}$)($1-e^{0.16 \ yr^{-1}}$)

= 10.1 (mg/m^2-year)

B. Calculate the annual drainage volume from Equation 7-3:

$$Dv = (L - S)\left[\frac{0.001 \ A_s}{(1 - L)(1 - S)}\right] \qquad (7\text{-}10)$$

where:

D_v = drainage volume (m^3 water/m^2-yr)
L = initial moisture content of sludge (kg/kg)
S = storage capacity of sludge (kg/kg)
A_s = annual sludge application rate (kg/m^2-yr)
0.001 = inverse of the density of water (m^3/kg)

$$D_v = 0.95-0.90 \; \frac{0.001(m^3/kg) \times 5(kg/m^2\text{-year})}{(1-0.95)(1-0.90)}$$

$$= 0.05(m^3/m^2\text{-year})$$

C. Calculate the predicted leachate concentration (X_i) from Equation 7-4:

$$X_i = \frac{0.001 \; F_i}{R + IR + D_v} \qquad (7\text{-}11)$$

where:

F_i = mass flux derived from Equation 7-1a or b (mg/m^2-yr)
R = recharge (m^3/m^2-yr)
IR = irrigation (m^3/m^2-yr)

Hexachlorobenzene

$$X_i = \frac{0.001(m^3/\ell) \times 10.1(mg/m^2\text{-year})}{0.5(m^3/m^2\text{-year}) + 0.05(m^3/m^2\text{-year})}$$

$$= 0.018 \; (mg/\ell)$$

D. Compare X_i to the reference water concentration, RWC:

	X_i	RWC
Hexachlorobenzene	0.018	0.000021

E. If X_i >RWC, as is the case for hexachlorobenzene, it is necessary to proceed to Tier 2.

7.5.1.2. TIER 2 --

7.5.1.2.1. Unsaturated Zone Calculations --

A. Calculate the steady-state moisture content of the soil for each layer in the unsaturated zone as

$$f = f_s \; \frac{R + D_v}{K_{sat}} \, [1/(2b + 3)] \qquad (7\text{-}12)$$

where:

f = steady-state moisture content (m^3/m^3)

f_s = saturated moisture content for the unsaturated zone soil (m^3/m^3)

R = net recharge (m^3/m^2-year)

D_v = drainage volume (m^3/m^2-year)

K_{sat} = saturated hydraulic conductivity of the unsaturated zone soil (m/year)

b = negative one times the slope of the log-log plot of matric potential and saturated moisture content (dimensionless)

Layer 1

$$f = 0.39 \text{ m}^3/\text{m}^3 \; \frac{0.5 \text{ m/year} + 0.05 \text{ m/year}}{10^4 \text{ m/year}} \; 1/[(2)\ (4) + 3]$$

$$= 0.16 \text{ m}^3/\text{m}^3$$

NOTE: If multiple layers are present in the unsaturated zone, solve for each layer.

B. Calculate the steady-state travel time of the water across each unsaturated zone soil layer as

$$T_u = (hy)\ (f)\ (R+D_v) \qquad (7\text{-}13)$$

where:

T_u = steady-state travel time across an unsaturated zone soil layer (years)

hy = depth to groundwater or thickness of the unsaturated zone beneath the site (m)

Layer 1

$$T_{u1} = (1.0 \text{ m})\ (0.16 \text{ m}^3/\text{m}^3)/(0.5 \text{ m/year} + 0.05 \text{ m/year})$$

$$= 0.29 \text{ year}$$

NOTE: If multiple layers are present in the unsaturated zone, solve for each layer.

C. Calculate the total travel time of the water across the unsaturated zone

$$T_T = T_{u1} + T_{u2} + \ldots \qquad (7\text{-}14)$$

where:

T_T = total travel time across all layers of the unsaturated zone (years)

$$T_T = 0.29 \text{ year}$$

D. Calculate the average velocity of the water across the unsaturated zone as

$$V_{ave} = (hy_1 + hy_2 + \ldots)/T_T \qquad (7\text{-}15)$$

where:

V_{ave} = average velocity across the unsaturated zone (m/year)

$hy\#$ = thickness of each unsaturated zone layer where # = 1, 2, ...

$$V_{ave} = 1.0 \text{ m}/0.29 \text{ year}$$

$$= 3.45 \text{ m/year}$$

E. Calculate the average moisture content of the unsaturated zone as

$$f_{ave} = R/V_{ave} \qquad (7\text{-}16)$$

where:

f_{ave} = average moisture content of the unsaturated zone (m^3/m^3)

$$f_{ave} = \frac{0.5 \text{ m/year} + 0.05 \text{ m/year}}{3.45 \text{ m/year}}$$

$$= 0.16 \text{ m}^3/\text{m}^3$$

F. Obtain the unsaturated zone partition coefficient, Kd, and unsaturated zone degradation rate for each contaminant from Appendix C of the Landfill Methodology Document (U.S. EPA, 1986). Select Kd values based on soil type. If there is more than one type of soil (more than one layer) in the unsaturated zone, use a weighted average for Kd. Calculate the weighted average by summing the products of the thickness of each layer and the Kd for each soil type (layer) and dividing by the total thickness of all layers.

Contaminant	Kd (ℓ/kg)	Degradation Rate ($year^{-1}$)
Hexachlorobenzene	0.4	0.16

G. Calculate the retardation factor for the contaminant in the unsaturated zone as

$$Rd = 1 + (B_u \ Kd/f_s) \qquad (7\text{-}17)$$

where:

Rd = retardation factor (dimensionless)

B_u = bulk density of unsaturated zone material (kg/m^3)

Kd = partition coefficient (ℓ/kg)

f_s = saturated moisture content for the unsaturated zone material (m^3/m^3)

NOTE: If multiple layers are present in the unsaturated zone, calculate a weighted average retardation factor using weighted average values for bulk density and saturated moisture content (weight according to layer thickness).

Hexachlorobenzene

$$Rd = 1 + \frac{(0.4\ \ell/kg)\ (0.001\ m^3/\ell)\ (1400\ kg/m^3)}{0.39\ m^3/m^3}$$
$$= 2.44$$

H. For degradable contaminants, calculate the concentration of contaminant leaving the unsaturated zone accounting for degradation as

$$Cus = X_i \exp [(-1)\ (k)\ (T_T)\ (RF)] \qquad (7\text{-}18)$$

where:

Cus = contaminant concentration exiting the unsaturated zone (mg/ℓ)

Hexachlorobenzene

$$Cus = 0.018\ mg/\ell \exp [(-1)\ (0.16\ year^{-1})\ (0.29\ year)\ (2.44)]$$
$$= 0.016\ mg/\ell$$

7.5.1.2.2. MINTEQ Adjustment for Geochemical Reactions -- For metallic contaminants, determine the amount of concentration reduction that will occur due to geochemical reactions in the saturated flow system (aquifer) using the MINTEQ graphs given in Appendix C of the Landfill Methodology Document (U.S. EPA, 1986).

7.5.1.2.3. Tier 2 Intermediate Comparison to Reference Water Concentrations -- Compare the Tier 2 concentrations at the base of the unsaturated zone, as calculated without allowing for dispersion, with the reference water concentration. The final Tier 2 concentrations for hexachlorobenzene are given above.

Hexachlorobenzene

Concentration after Allowing for Decay = 0.016 mg/ℓ

RWC = 0.000021 mg/ℓ

For hexachlorobenzene, the Tier 2 concentration at the base of the unsaturated zone, without accounting for dispersion, is greater than the RWC. Therefore, the Tier 2 analysis needs to be continued using the CHAIN and AT123D models.

7.5.1.2.4. CHAIN Model -- Since the Tier 2 result presented previously is not less than the RWC, it is necessary to run the CHAIN analytical transport model to predict the contaminantion concentration at the base of the unsaturated zone. The input data required by the CHAIN model are the leachate concentration (X_i), the total recharge (R + IR) as the flux rate, a continuous pulse as the input pulse time, the retardation factor (RF) and the degradation rate (k). The dispersion coefficient used in CHAIN is calculated as one-tenth the depth to groundwater (unsaturated zone thickness, hy) times the average groundwater velocity in the unsaturated zone (V_{ave}).

For organic contaminants, compare the maximum model-predicted concentration with the RWC values. If the model-predicted concentration is less than the RWC, no further Tier 2 analysis is required. If not, the saturated transport model AT123D should be run.

For inorganic contaminants, take the maximum model-predicted concentrations and enter the appropriate curves in Appendix C of the Landfill Methodology Document (U.S. EPA, 1989) to predict the resulting concentration after geochemical reaction. If the resulting concentration is less than the threshold, no further Tier 2 analysis is required. If not, the resulting concentrations should be entered into the saturated transport model AT123D.

The CHAIN model results for this example problem are:

	Unsaturated Model Results (mg/ℓ)	Reference Water Concentration (mg/ℓ)
Degradable Organics		
Hexachlorobenzene	0.016	0.000021

The unsaturated model result for hexachlorobenzene is above the reference concentration value; therefore, the saturated transport model AT123D needs to be run.

7.5.1.2.5. AT123D Model -- Since the CHAIN model results are not below the reference concentration for hexachlorobenzene, it is necessary to run the AT123D saturated zone transport model to predict the contaminant concentration at the site boundary. The peak contaminant concentrations and the pulse time as predicted by the CHAIN model are used as inputs to AT123D. The other input data required by AT123D are the degradation rate (k), the retardation factor (calculated for the saturated zone using the saturated distribution coefficient, bulk density and porosity), the groundwater velocity (calculated as the saturated hydraulic conductivity times the hydraulic gradient divided by the effective porosity), the longitudinal dispersion coefficient (calculated as one-tenth the distance to the landfill boundary times the groundwater velocity), and the transverse and vertical dispersion coefficients (calculated as one-tenth the longitudinal dispersion coefficient).

The AT123D model results for the example problem are:

Degradable Organics	Saturated Model Results (mg/ℓ)	RWC (mg/ℓ)
Hexachlorobenzene	0.013	0.000021

The saturated model results for hexachlorobenzene are well above the RWC. Therefore, this application would be unacceptable, and the applicant may desire to proceed to Tier 3 by experimentally determining the contaminant concentration in the leachate. If the predicted output concentrations were very close to the RWC, the permit writer may require a characterization of input parameter uncertainty and additional runs to determine sensitivity to that uncertainty.

If background concentrations of hexachlorobenzene are present in the groundwater, these concentrations would be added to the saturated model results and this total concentration would be compared to the reference water concentration.

7.5.2. National Criteria Site-Specific Application. To set national criteria, the methodology is applied in reverse order with the same site- and chemical-specific inputs. In this case, the starting point is the RWC and the endpoint is the reference starting acceptable leachate concentration (RX) or the acceptable mass of contaminant added per unit area each year (RF). Example calculations for the trial scenario are provided below for hexachlorobenzene using the input parameters provided in Table 7-3.

Hexachlorobenzene

For hexachlorobenzene, the RWC is 0.000021. From the previous section, when AT123D was applied, a saturated zone input concentration of X = 0.016

mg/ℓ yielded an output concentration of C = 0.013 mg/ℓ. The input concentration (RC) required to reach the RWC is, therefore,

$$RC = (0.000021)(0.016/0.013)$$

$$= 0.000026 \text{ mg}/\ell$$

Based on the above calculation, the RWC will be reached at the site boundary if the input concentration to the aquifer is 0.000026 mg/ℓ. In like fashion, Equation 7-7 is applied to determine what the input to the unsaturated zone would have to be to obtain an output concentration of RC = 0.000026 mg/ℓ. In this case, RX = RC (Co/C). From the previous section, an input concentration of Co = 0.018 mg/ℓ hexachlorobenzene produced an output concentration of C = 0.016 mg/ℓ hexachlorobenzene when the CHAIN code was applied to the site. Substituting for RC, C and Co in Equation 7-7, provides the following:

$$RX = (0.000026)(0.018/0.016)$$

$$= 0.000029 \text{ mg}/\ell$$

Therefore, the predicted leachate concentration of hexachlorobenzene cannot equal or exceed 0.000029 mg/ℓ without groundwater at the property boundary exceeding the RWC.

The limiting predicted leachate concentration (RX) is converted to an equivalent annual mass flux of contaminant (RF) as follows:

$$\begin{aligned} RF &= RX\ (R + IR + D_v)(1000) \\ &= (0.000029)(0.55)(1000) \qquad (7\text{-}19) \\ &= 0.016\ (\text{mg/m}^2\text{-yr}) \end{aligned}$$

The annual application rate of pollutant in sludge (R_p, in mg/m^2-year) required to produce that annual mass of hexachlorobenzene after accounting for degradation is calculated as

$$R_p = \frac{RF}{k}(e^k - 1)$$

$$= \frac{0.016(\text{mg/m}^2\text{-year})}{0.16}(e^{0.16} - 1) \qquad (7\text{-}20)$$

$$= 0.017 \text{ mg/m}^2\text{-year}$$

[Note that the units of R_p differ from those of RP_a (kg/ha-year) used in Chapter 4.] The above mass is divided by the annual sludge application rate, 5 kg/m^2-year, to yield an RSC of hexachlorobenzene in sludge of 0.0034 mg/kg.

$$\begin{aligned} RSC &= R_p \div A_s \\ &= (0.017) \div 5 \\ &= 0.0034 \text{ mg/kg} \end{aligned}$$

8. CRITERIA CALCULATION METHODS FOR THE VAPORIZATION EXPOSURE PATHWAY

8.1. OVERVIEW OF THE METHOD

Vapor loss following land application of sludge has been identified as a possible pathway of concern for migration of toxic chemicals (see Section 3.5.). A tiered risk assessment approach using three levels of analysis is outlined in this chapter. Regardless of the level of assessment (Tiers 1 through 3), the basic approach requires some degree of simulation of the movement of vapors up from the sludge into the atmosphere. Tier 1 involves a simple partial pressure calculation using Henry's Law to predict maximum potential vapor levels above the sludge. This is a very conservative estimate of concentration, since it does not account for air/sludge matrix partitioning or dispersion in the atmosphere.

Tier 1 estimates air concentrations of contaminants in an atmosphere at equilibrium with the liquid sludge. This represents the worst-case situation of a worker in the land application site following application of liquid sludge and under highly stable atmospheric conditions. This scenario is analogous to that for the tractor operator exposed to dust as evaluated in Chapter 5. Both involve short-term and relatively infrequent high-level exposures to agricultural workers. Exposures of agricultural workers are evaluated by means of OSHA or NIOSH exposure limits, rather than limits based on chronic exposures (RfD or q_1*).

In addition to providing a means to evaluate acute exposures to workers, Tier 1 may also be viewed as a rough public health screening procedure to determine whether it is necessary to proceed to Tiers 2 and 3, which examine the potential for risk from long-term exposures at the property boundary.

To use Tier 1 as a screening tool, the result for a given compound is compared with the reference air concentration, RAC*, which is based on chronic exposures. The screening use of Tier 1 is illustrated in Figure 8-1.

If the Tier 1 estimated air concentrations are lower than the RAC, no further evaluation of the contaminant is necessary. If the predicted concentration exceeds the RAC, the applicant may opt to proceed to Tier 2 where transport through the soil cover and atmospheric dispersion are taken into consideration.

The Tier 2 analysis is conducted in two steps. In the first step, a simple mass balance is used to predict the average vapor flux from the land application site. An atmospheric dispersion model is then used to predict downwind atmospheric concentrations at the location of receptors. Because chronic exposure is the primary concern, the model selected for use was that derived to predict long-term atmospheric concentrations following closure of hazardous waste landfills (Environmental Science and Engineering, 1985). Degradation and deposition are not accounted for because travel times will be relatively short. Once again, if predicted concentrations exceed the RAC, the analysis can go to Tier 3.

Tier 3 utilizes a modeling approach but allows the applicant to input measured vapor flux rates for the source term. This accounts for the partitioning between the atmosphere and the sludge matrix. Thus, the three tiers can be summarized as follows:

Tier 1 -- Simple -- Compare calculated equilibrium concentrations with reference air concentration (RAC).

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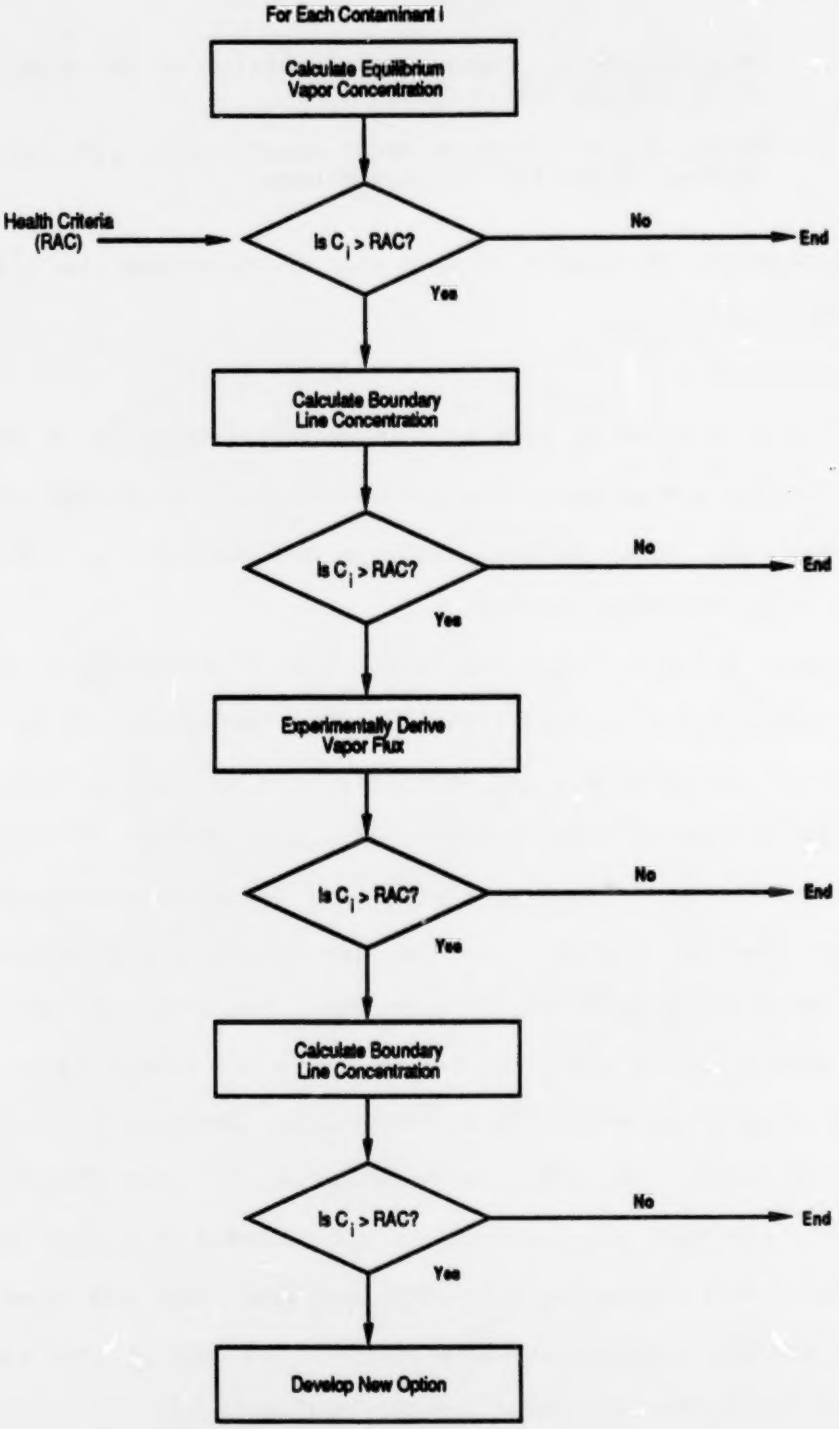
*The methods for deriving RAC for each sludge contaminant can be found in Section 8.4.3.


For Each Contaminant i
Calculate Equilibrium Vapor Concentration
Health Criteria (RAC)
Is C_i > RAC?
No
End
Yes
Calculate Boundary Line Concentration
Is C_i > RAC?
No
End
Yes
Experimentally Derive Vapor Flux
Is C_i > RAC?
No
End
Yes
Calculate Boundary Line Concentration
Is C_i > RAC?
No
End
Yes
Develop New Option

C_i = Atmospheric Concentration of Contaminant i

FIGURE 8-1

Logic Flow for Vapor Loss Pathway Evaluation of Land-Applied Sludges

Tier 2 -- More Complex -- Compare model results to RAC using estimates for the source term.

Tier 3 -- Most Complex -- Compare model results using experimentally derived values for the source term.

The procedures and details of each tier in the methodology are described in the following sections.

8.2. ASSUMPTIONS

To apply a methodology such as that presented here, it is necessary to make simplifying assumptions. The assumptions, stated or implied, required to implement the vapor pathway analysis are outlined in Table 8-1 and discussed in the following sections.

8.2.1. Vapor Pressure. The Tier 1 and Tier 2 methodologies require the vapor pressure (vapor concentration) of the contaminant to be specified. Because vapor pressures are not routinely measured, the methodologies use Henry's Law to specify vapor concentration as a function of liquid concentration. Henry's Law is most appropriate for low aqueous concentrations and low solids content sludges. As the concentration and solids contents increase, Henry's Law will tend to overpredict vapor pressure as a result of activity effects and partitioning between solid and liquid phases. As such, the use of Henry's Law represents a conservative approach.

8.2.2. Loss Rate. The Tier 2 methodology assumes that sludge is applied periodically and that all contaminants will volatilize during the application period. This assumption represents the worst case and leads to calculation of maximum possible exposure levels. The use of this conservative approach is consistent with other exposure methodologies.

The Tier 3 methodology assumes that the loss rate of contaminants is controlled by diffusion of contaminants through the soil. The loss rate is then independent of windspeed. This assumption is necessary to measure

TABLE 8-1

Assumptions for the Vapor Pathway Methodology

Functional Area	Assumptions	Ramifications
Vapor Pressure	Vapor concentration can be defined as a function of liquid concentration by use of Henry's Law.	Is appropriate for low concentrations an low solids contents. As concentrations and solids contents increase, method wil tend to overpredict vapor concentrations Variations will also arise from temperature and pressure changes.
Loss Rate	Tier 2 assumes that all volatile contaminants will be lost during the period between applications.	Assumption represents maximum possible long-term average loss rate and therefor overpredicts total flux.
	Tier 3 assumes that loss rate is controlled by diffusion through soil.	Appropriate assumption if contaminants are incorporated into soil or have infil trated into soil. Represents long-term average conditions.
Atmospheric Transport	Tier 1 assumes no atmospheric dilution.	Will grossly overpredict exposure, as i consistent with Tier 1 approach.
	Tiers 2 and 3 assume constant wind speed and direction and that receptor is located downwind along centerline of plume.	Assumption predicts maximum possible exposure to receptor.
	Tiers 2 and 3 assume stable atmospheric conditions.	Assumption predicts maximum possible downwind concentrations.

loss rates in the laboratory that are representative of those expected in the field. This assumption is not appropriate for describing direct volatilization from solid or liquid surfaces and, therefore, will not accurately describe volatile losses from liquid sludge applied directly to the soil surface. The assumption is appropriate for describing volatile losses when contaminants must first diffuse to the atmosphere and is, therefore, appropriate for describing losses when contaminants are incorporated into the soil or after they have infiltrated into the soil. Because contaminants will remain on the soil surface for only a short period of time before infiltrating, the assumption is judged to reasonably represent long-term average conditions.

8.2.3. Atmospheric Transport. The Tier 1 methodology assumes no atmospheric dilution of contaminants. The result of this assumption will be to grossly overpredict atmospheric contaminant concentrations. This approach is clearly conservative and is consistent with the Tier 1 approach.

To simplify use of the atmospheric transport model in Tiers 2 and 3, it is assumed that the wind speed and direction are constant and that the receptor of concern is always located downwind along the centerline of the plume. The effect of these assumptions is to predict the maximum possible downwind atmospheric concentrations and, therefore, the maximum possible exposure. This conservative approach is consistent with the other exposure methodologies.

In applying the atmospheric model, it is assumed that stable atmospheric conditions will always be encountered. The effect of this assumption will be to maximize the resulting downwind concentrations, thereby predicting the maximum possible exposure levels. Again, this conservative approach is consistent with other exposure methodologies.

8.3. CALCULATIONS

8.3.1. Tier 1. The first tier embodies a simple comparison of source term vapor concentrations to the RAC value. Source term vapor concentrations are predicted on the basis of sludge contaminant concentrations and Henry's Law. This does not account for any dispersion in the atmosphere and, thereby, overpredicts concentrations. Henry's Law describes vapor compositions over dilute solutions. The relation is given in the following equation:

$$P_i = H_i Cl_i \tag{8-1}$$

where:

P_i = partial pressure of i above the solution (atm)
H_i = the Henry's Law constant for i (atm-m³/mol)
Cl_i = the concentration of i in the solution (mole/m³)

Assuming the vapor phases act as ideal gases, the partial pressure can be translated to an atmospheric concentration using Dalton's Law:

$$P_i = y_i P_t \tag{8-2}$$

where:

y_i = mole fraction of i in the gas phase (dimensionless)
P_t = total pressure in the system (atm)

For the land application environment of interest here, P_t can be set at 1 atm. Then combining Equations 8-1 and 8-2, atmospheric concentration y_i can be calculated as follows:

$$P_t y_i = H_i Cl_i \tag{8-3}$$

With the molecular weight of the contaminant and air and the molar volume of air, this can be converted to an atmospheric concentration in terms of weight fraction or mass per volume.

An alternate approach is to use a dimensionless modified Henry's Law constant H' defined as follows:

$$H' = Cv_i/Cl_i \tag{8-4}$$

where:

Cv_i = concentration of i in air (mass/volume)
Cl_i = concentration of i in water (mass/volume)

This eliminates the need for conversions to obtain the atmospheric concentration of the contaminant in the desired units. H can be converted to H' by using the Universal Gas Law to calculate atmospheric concentration (moles/volume) from partial pressure.

The use of the Henry's Law approach assumes ideal gas behavior and dilute solutions. Both assumptions are appropriate for the levels of volatile contaminants expected in municipal sludge, since handling and treatment before land application are likely to have allowed high concentrations to diminish through the vaporization process. In empirical work with municipal sludge, English et al. (1980) found Henry's Law to be useful in predicting atmospheric concentrations of ammonia. Values for the Henry's Law constant can be obtained from the literature or calculated from physical properties.

Henry's Law Constants and modified Henry's Law Constants for contaminants of interest are provided in Appendix C of the Landfill Methodology Document (U.S. EPA, 1986).

The Tier 1 methodology utilizing Henry's Law constant is analogous to predicting the vapor concentration above a liquid surface (surface impoundment). This approach is clearly conservative for analyzing land application of sludge. The method approximates the vapor concentrations that may be seen immediately after surface spreading of liquid sludge, and overpredicts vapor concentrations associated with surface application of dewatered sludge and sludge injection or incorporation. To evaluate potential effects of short-term concentrations on workers in the field, the estimated vapor concentrations are compared with OSHA or NIOSH concentration limits for workers. To use as a screening tool to identify chemicals that could cause chronic effects beyond the boundary site, the estimated vapor concentrations are compared with the appropriate RAC. If the vapor concentrations do not exceed the RAC, no further analysis is required. If the vapor concentrations do exceed the reference doses, the applicant can decide if the greater accuracy of Tiers 2 or 3 is likely to be advantageous and, therefore, worth the added effort.

8.3.2. Tier 2. The first tier methodology treats the applied sludge as though it were a solution in a surface impoundment. The vapor concentrations of contaminant are a result of direct volatilization from the surface and subsequent diffusion into the air column. In actuality, a number of modes of contaminant release may occur with land application.

In the case of surface application of liquid sludge, the liquid will be on the surface and available for direct volatilization immediately after application. In time, however, the liquid contaminants will infiltrate into the soil column. Volatilization rates will then be reduced because of interactions between contaminants and the soil and the need to diffuse through the soil to reach the atmosphere.

In the case of surface application of dewatered sludge, volatilization rates will be limited by the relatively high concentration of solids and by interactions between the contaminants and sludge solids. Drying of the sludge can lead to formation of a surface crust, which will further reduce volatilization rates.

Volatilization rates for injected or incorporated sludges will be controlled by diffusion through the soil and possibly by interactions between organic vapors and the soil.

As noted above, volatilization from sludge applied to the land may be controlled by a variety of mechanisms, some of which are complex and difficult to predict. For the purposes of a Tier 2 methodology, it is desirable to have a simple model that reasonably represents worst-case conditions. In the case of land application, it is assumed that the worst case with respect to chronic exposure would be repeated periodic applications of sludge to the land. Such application would result in the highest long-term average exposure levels. For a given application, the highest long-term exposure levels would occur if all the volatile components present entered the atmosphere during the period between applications. The Tier 2 methodology, therefore, predicts the average volatile contaminant flux, assuming all contaminants volatilize during the application period.

The first step in applying the Tier 2 methodology is to calculate the average annual contaminant application rate. If the contaminant concentration is expressed on a total dry weight basis, the contaminant application rate is given by

$$RP_a = (AR_a)(SC) \times 10^{-3} \qquad (8\text{-}5)$$

where:

RP_a = the annual contaminant application rate (kg/ha-yr)
AR_a = the annual dry weight sludge application rate (Mg/ha-yr)
SC = the dry weight concentration of contaminant in sludge (mg/kg)
10^{-3} = conversion factor (kg-kg/Mg-mg)

If the contaminant concentration is only given in terms of a liquid phase concentration (results of leaching test), the liquid phase concentration can be converted to an equivalent dry weight concentration by

$$SC = (C_l/S)\left[K_{oc}\,(f_{oc})(S) + \frac{(1-S)}{\gamma_l}\right] \qquad (8\text{-}6)$$

where:

C_l = the contaminant concentration in the liquid (mg/ℓ)
S = the solids content of the sludge (kg/kg)
K_{oc} = the organic carbon distribution coefficient for the contaminant (ℓ/kg)
f_{oc} = the organic carbon content of the sludge solids (kg/kg)
γ_l = the density of the sludge liquid (kg/ℓ)

The dry weight concentration calculated using the above expression can then be used in Equation 8-5 to determine the contaminant application rate.

Assuming that all contaminants are lost to volatilization during the application period, the yearly contaminant application rate is equal to the contaminant flux rate from volatilization. Converting the flux rate to units consistent with the atmospheric dispersion model

$$Q_V = \frac{RP_a}{(0.001)(10{,}000)(31{,}536{,}000)} \qquad (8\text{-}7)$$

$$= RP_a \div (3.2\text{x}10^8)$$

where:

Q_V = contaminant flux rate due to volatilization (g/m²-sec)
0.001 = conversion constant (kg/g)
10,000 = conversion constant (m²/ha)
31,536,000 = conversion constant (sec/yr)

The assumption that all volatile contaminants are lost through the atmosphere during the period of time between applications is conservative in that it does not account for migration through runoff or infiltration. Vaporization is a first-order phenomenon with vapor concentrations (and hence flux rates) proportional to the concentration left in the sludge. If vaporization rates are not sufficient to reduce the mass of contaminant added each year, the concentration of contaminant in the soil's surface will increase to a point where it can sustain a flux rate equal to the mass added in each application.

As noted above, this approach ignores losses that are due to infiltration and runoff. This assumption is not appropriate for contaminants of low volatility since they remain in the soil long enough for precipitation events to occur and affect a significant fraction of the residuals. Therefore, the vapor loss pathway is only applied to the more volatile contaminants.

The emission rate thus derived is used to calculate atmospheric concentrations at the boundary using a source-receptor ratio (SRR).

$$C(X)i = Q_v \times SRR \qquad (8\text{-}8)$$

where C(X)i is the atmospheric concentration (g/m^3), X is the downstream distance from the source to the receptor (m), and SRR (sec/m) is calculated in Equation 8-9 (Environmental Science and Engineering, 1985):

$$SRR = 2.032 \left[\frac{X_o{}^2V}{(r' + Xy)\ \nu\ \sigma z)}\right] \qquad (8\text{-}9)$$

where:

X_o = the characteristic length of the land application area, assumed to be a square (m)

V = vertical term which is a function of source height and σz (unitless)

r' = distance from the landfill center to the receptor or point of compliance (m)

Xy = lateral virtual distance (m)

ν = mean wind speed (m/sec)

σz = standard deviation of the vertical concentration distribution (m)

The vertical term is set at

$$V = \frac{(2\pi)\quad(T_Z)}{2L} \text{ for } \sigma_Z/L \geq 1.6 \qquad (8\text{-}10)$$

and

$$V = e\left[-1/2\left(\frac{H}{\sigma_Z}\right)^2 +\right] \sum_{n=1}^{\infty} 2e\left\{[-1/2(\frac{2nL}{\sigma_Z})^2]\right\} \text{ for } \sigma Z/L<1.6 \qquad (8\text{-}11)$$

where:

H = contaminant release height (m)
L = mixing layer height (m)

Under stable conditions, as assumed here, the mixing layer height L is assumed infinite. Therefore, Equation 8-11 is used, and the second (summation) term of the equation goes to zero. Since the contaminant is released from the ground surface, H = 0 and the first (exponential) term of Equation 8-11 becomes 1. Therefore, V = 1 for the ordinary conditions of this analysis. The lateral virtual distance, Xy, is calculated as follows:

$$X_y = \left(\frac{X_o}{\pi}\right) \mathrm{Cot} \left(\frac{\Delta\emptyset'}{2}\right) \qquad (8\text{-}12)$$

where:

$\Delta\emptyset'$ = sector width (radians) [for 22.5°, $\Delta\emptyset'$ = 0.393]

The standard deviation in the vertical direction, σz, can be taken from tables for various distances and stability classes or calculated as indicated in Table 8-2.

8.3.3. Tier 3. The Tier 3 methodology involves a similar approach to the Tier 2 methodology except that empirically derived flux rates are input to the atmospheric dispersion model. To use the Tier 3 methodology, it is necessary to measure flux rates in the laboratory. In all sludge application scenarios, it is assumed that volatilization rates will be controlled by diffusion through the soil column to the atmosphere rather than by exchange at the air-soil-surface interface. Therefore, the laboratory measurements should involve pumping contaminant-free air into a sealed container containing a soil column representative of the application site. The air leaving the container should be pumped through a suitable trap for capturing the contaminant. The trap should then be analyzed periodically to quantify volatilization rates. A toxicity characteristic vapor procedure is to be promulgated in 1986 for identifying hazardous wastes. This analytical procedure would be appropriate for determining vapor concentrations above a sludge.

8.3.4. Setting National Criteria. To establish sludge concentration criteria for volatile contaminants, it is necessary to operate the methodology provided here in a reverse mode similar to the approach

TABLE 8-2

Parameters Used To Calculate σ_z*

Pasquill Stability Category	x (km)	$\sigma_z = a\ x\ (mb)^b$ a	b
Very Unstable**	0.10 - 0.15	158.080	1.04520
	0.16 - 0.20	170.222	1.09320
	0.21 - 0.25	179.520	1.12620
	0.26 - 0.30	217.410	1.26440
	0.31 - 0.40	258.890	1.40940
	0.41 - 0.50	346.750	1.72830
	0.51 - 3.11	453.850	2.11660
	3.11	+	+
Unstable**	0.10 - 0.20	90.673	0.93198
	0.21 - 0.40	98.483	0.98332
	0.40	109.300	1.09710
Slightly Unstable**	0.10	62.141	0.91465
Neutral	0.10 - 0.30	34.459	0.86974
	0.31 - 1.00	32.093	0.81066
	1.01 - 3.00	32.093	0.64403
	3.01 - 10.00	33.504	0.60586
	10.01 - 30.00	36.650	0.56589
	30.00	44.053	0.51179
Slightly Stable	0.10 - 0.30	23.331	0.81956
	0.31 - 1.00	21.628	0.75660
	1.01 - 2.00	21.628	0.63077
	2.01 - 4.00	22.534	0.57154
	4.01 - 10.00	24.703	0.50527
	10.01 - 20.00	26.970	0.46713
	20.01 - 40.00	35.420	0.37615
	40.00	47.618	0.29592

TABLE 8-2 (cont.)

Pasquill Stability Category	x (km)	$\sigma_Z = a\ x\ (mb)^b$	
		a	b
Stable	0.10 - 0.20	15.209	0.81558
	0.21 - 0.70	14.457	0.78407
	0.71 - 1.00	13.953	0.68465
	1.01 - 2.00	13.953	0.63227
	2.01 - 3.00	14.823	0.54503
	3.01 - 7.00	16.187	0.46490
	7.01 - 15.00	17.836	0.41507
	15.01 - 30.00	22.651	0.32681
	30.01 - 60.00	27.084	0.27436
	60.00	34.219	0.21716

*Source: Environmental Science and Engineering, 1985

**If the calculated value of σ_Z exceeds 5000 m, σ_Z is set to 5000 m.

+ σ_Z is equal to 5000 m.

discussed in the previous section for the groundwater pathway. That is, the reference air concentration (RAC, in mg/m^3) is taken as input to determine the maximum allowable concentration in the source sludge. From Equation 8-8, the compliance point concentration (C_c, in mg/m^3) is defined as follows:

$$C_c = (Q_v)(SRR) \times 10^3 \tag{8-13}$$

where:

Q_v = contaminant flux rate due to volatilization (g/m^2-sec)
SRR = source-receptor ratio (sec/m)

Since SRR is characteristic of a site and not concentration dependent, a single value can be calculated for a representative site. Rearranging and setting C_c = RAC, the reference flux (RQ) required to meet RAC is defined as follows:

$$RQ = RAC/(SRR \times 10^3) \tag{8-14}$$

From Equation 8-7, the limiting flux RQ is also a function of the limiting annual contaminant application rate (RP_a, in kg/ha-year) according to Equation 8-15:

$$RQ = RP_a \div (3.2 \times 10^8) \tag{8-15}$$

where:

3.2×10^8 = conversion factor (kg-m^2-sec/g-ha-yr)

Therefore

$$RP_a = RAC\ (3.2 \times 10^8)/(SRR \times 10^3) \tag{8-16}$$

Then, from Equation 8-5, dividing by the annual sludge application rate (AR_a, in Mg/ha-year) converts Equation 8-16 to the reference sludge concentration (RSC, in mg/kg DW) according to Equation 8-17:

$$RSC = \frac{RAC\ (3.2 \times 10^5)}{(SRR)(AR_a \times 10^{-3})} \tag{8-17}$$

where:

RAC = reference air concentration (mg/m^3)
$3.2x10^5$ = conversion factor ($kg\text{-}m^2\text{-}sec/mg\text{-}ha\text{-}yr$)
SRR = source-receptor ratio (sec/m)
AR_a = annual sludge application rate (Mg DW/ha-year)
10^{-3} = conversion factor (kg-kg/Mg-mg)

8.4. INPUT PARAMETER REQUIREMENTS

A number of input parameters are required to calculate exposure to vapors from the land application of sludge. The following summarizes those inputs and provides information on where data may be obtained.

8.4.1. Fate and Transport: Pathway Data.

1. Vertical Term for Transport (V) -- It is conservatively assumed that atmospheric conditions are stable. Therefore, V will always be equal to 1 (see Equation 8-11).
2. Lateral Virtual Distance (X_y) -- Equal to X_0 cot ($\Delta\theta'/2$), where $\Delta\theta'$ is the sector width in radians. It is assumed that the sector width is 0.393 (22.5°), therefore $X_y = 2.84X_0$.
3. Average Wind Speed (ν) -- Obtained from local weather station.
4. Length or Width of Source (X_0) -- Obtained from site map or plans. It is assumed that land application areas are square.
5. Distance from Center of Source to Receptor (r') -- Obtained from site plans. r' is taken as the sum of one-half the width of the total land application area ($X_0/2$) plus the width of the buffer area from the landfill area to the property boundary.
6. Standard Deviation of the Vertical Concentration Distance (σZ). Atmospheric conditions are assumed to be stable.
7. Annual Sludge Application Rate (AR_a) -- Obtained from operating plan and normalized to an annual basis.

8.4.2. Fate and Transport: Chemical-Specific Data.

1. Contaminant Concentration in Sludge (SC) or Sludge Liquid (C_l) -- Obtained from analysis of the sludge or from application of the TCLP as described in Appendix A of the Landfill Methodology Document (U.S. EPA, 1986). Equation 8-6 can be used to convert between TCLP measured levels and total sludge levels for organic contaminants. Note that C_l, the concentration in sludge liquid, refers only to the concentration in the liquid phase, not the wet weight concentration of the whole liquid sludge.

2. Henry's Law Constant (H') -- Obtained from Appendix C of the Landfill Methodology Document (U.S. EPA, 1989), or derived directly.

8.4.3. Health Effects Data. A reference air concentration (RAC, in mg/m^3) will be defined as an ambient air concentration used to evaluate the potential for adverse effects on human health as a result of land application of sludge. That is, for a given land application site, and given the practice definitions and assumptions stated previously in this methodology, the criterion for a given sludge contaminant is that concentration in the sludge which cannot be exceeded, and is calculated to result in air concentrations below the RAC at a compliance point downwind from the site. For the RAC to be exceeded would be a basis for concern that adverse health effects may occur in a human population in the site vicinity.

RAC is determined based upon contaminant toxicity and air inhalation rate, from the following general equation:

$$\text{Reference Air Concentration: } RAC = I_p/I_a \qquad (8\text{-}18)$$

where I_p is the acceptable chronic pollutant intake rate (in mg/day) based on the potential for health effects and I_a is the air inhalation rate (in m^3/day). This simplified equation assumes that the inhaled contaminant is absorbed into the body, by the lungs, at the same rate in humans as in the experimental species tested, or between routes of exposure (oral and inhalation). Also, this equation assumes that there are no other exposures of the contaminant from other sources, natural or manmade. I_p varies according to the pollutant evaluated and to whether the pollutant acts according to a threshold or nonthreshold mechanism of toxicity.

8.4.3.1. THRESHOLD-ACTING TOXICANTS -- Threshold effects are those for which a safe (subthreshold) level of toxicant exposure can be estimated. For these toxicants, RAC is derived as follows:

Reference Air Concentration: $$RAC = \left[\left(\frac{RfD \times bw}{RE}\right) - TBI\right] \div I_a \quad (8\text{-}19)$$

where:

RfD = reference dose (mg/kg/day)

bw = human body weight (kg)

TBI = total background intake rate of pollutant from all other sources of exposure (mg/day)

I_a = air inhalation rate (m^3/day)

RE = relative effectiveness of inhalation exposure (unitless)

The definition and derivation of each of the parameters used to estimate RAC for threshold-acting toxicants are further discussed below.

8.4.3.1.1. Reference Dose (RfD) -- When toxicant exposure is by ingestion, the threshold assumption has traditionally been used to establish an "acceptable daily intake," or ADI. The Food and Agricultural Organization and the World Health Organization have defined ADI as "the daily intake of a chemical that, during an entire lifetime, appears to be without appreciable risk on the basis of all the known facts at the time. It is expressed in milligrams of the chemical per kilogram of body weight (mg/kg)" (Lu, 1983). Procedures for estimating the ADI from various types of toxicological data were outlined by the U.S. EPA in 1980 (Federal Register, 1980). More recently the Agency has preferred the use of a new term, the "reference dose," or RfD, to avoid the connotation of acceptability, which is often controversial.

RfD will be defined for the purposes of this document as that dose, in mg/kg/day, which is estimated to be without effects in sensitive individuals during a lifetime inhalation exposure. RfD is estimated from observations in humans whenever possible. When human data are lacking, observations in animals are used, employing uncertainty factors as specified by existing Agency methodology.

Values of RfD for noncarcinogenic or systemic toxicity have been derived by several groups within the Agency. An effort is currently under way to verify these values and to produce a master list of RfDs for use by the various Agency programs. Most of the noncarcinogenic chemicals that currently are candidates for sludge criteria for the landfill pathway are included on the Agency's RfD list, and thus no new effort will be required to establish RfDs for deriving sludge criteria. For any chemicals not so listed, RfD values should be derived according to established Agency procedures (U.S. EPA, 1987b).

8.4.3.1.2. Human Body Weight (bw) and Air Inhalation Rate (I_a) -- An assumption of 20 m^3 inhalation/day by a 70-kg adult has been widely used in Agency risk assessments and will be used in this methodology for adults. Table 8-3 shows values of I_a for a typical man, woman, child and infant with a typical activity schedule, as defined by the International Commission on Radiological Protection (ICRP, 1975). Additional values have been derived for an adult with the same activity schedule (using upper-limit rather than average assumptions about respiration rates for each activity) and for an adult with normal respiration rates but whose work is moderately active and who practices 1 hour of heavy activity (strenuous exercise) per day (Fruhman, 1964; Astrand and Rodahl, 1977). Representative body weights have been assigned to each of these individuals to calculate a respiratory volume-to-body weight ratio. [Note: These ratios have been derived for illustrative purposes only.] The resulting ratio values range from 0.33 to 0.47 m^3/kg/day, all of which exceed the ratio value of 0.29 m^3/kg/day estimated from the 70-kg adult inhaling 20 m^3/day, as used currently by the Agency. Therefore, the typically assumed values for adults

TABLE 8-3

Daily Respiratory Volumes for "Reference" Individuals (Normal Individuals at Typical Activity Levels) and for Adults with Higher-than-Normal Respiratory Volume or Higher-than-Normal Activity Levels
(Volumes in m3)

	"Reference" Man[a]	"Reference" Woman[a]	Upper-Limit Adult	Active Adult	"Reference" Child[a] (10 years)	"Reference" Infant[a] (1 year)
8-hour working, light activity	9.6	9.1	12.0[b]	—	6.24	2.5 (10 hours)
8-hour working, moderate activity	—	—	—	14.4[c]	—	—
8-hour nonoccupational (light) activity	9.6	9.1	12.0[b]	—	6.24	—
7-hour nonoccupational (light) activity	—	—	—	8.4	—	—
1-hour heavy activity	—	—	—	2.5[c]	—	—
8-hour rest	3.6	2.9	7.0[d]	3.6	2.3	1.3 (14 hours)
Total daily respiratory volume	22.8	21.1	31.0	28.9	14.78	3.8
Body weight (kg)	70	58	65	65	33	10
Ratio of volume to body weight[e]	0.33	0.36	0.47	0.44	0.45	0.38

[a] Source: ICRP, 1975

[b] Upper-limit values for "ordinary man or woman," for "light" activity category (Åstrand and Rodahl, 1977)

[c] Averaged values for "ordinary man or woman," for "moderate" or "heavy" activity categories (Åstrand and Rodahl, 1977)

[d] Upper 95th percentile for adults, age 20-39 years, at rest (Fruhman, 1964)

[e] The inhalation volume to body weight ratios have been derived from the referenced values for illustrative purposes only.

may underestimate actual exposure. In cases where children or infants are known to be at specific risk, it may be more appropriate to use values of bw and I_a for children or infants.

8.4.3.1.3. Total Background Intake Rate of Pollutant (TBI) -- It is important to recognize that sources of exposure other than the sludge disposal practice may exist, and that the total exposure should be maintained below the RfD. Other sources of exposure include background levels (whether natural or anthropogenic) in drinking water, food or air. Other types of exposure that are due to occupation or habits such as smoking might also be included depending on data availability and regulatory policy. These exposures are summed to estimate TBI.

Data for estimating background exposure usually are derived from analytical surveys of surface, ground or tap water, from FDA market basket surveys and from air-monitoring surveys. These surveys may report means, medians, percentiles or ranges, as well as detection limits. Estimates of TBI may be based on values representing central tendency or on upper-bound exposure situations, depending on regulatory policy. Data chosen to estimate TBI should be consistent with the value of bw. Where background data are reported in terms of a concentration in air or water, ingestion or inhalation rates applicable to adults or children can be used to estimate the proper daily background intake value. Where data are reported as total daily dietary intake for adults and similar values for children are unavailable, conversion to an intake for children may be required. Such a conversion could be estimated on the basis of relative total food intake or relative total caloric intake between adults and children.

For example, in deriving the National Emission Standard for mercury, the average dietary contribution of 10 μg Hg/70 kg/day was subtracted from the assumed threshold of 30 μg/70 kg/day to give an allowable increment from inhalation exposure of 20 μg/70 kg/day. An assumed inhalation volume of 20 m^3/day for a 70-kg man was then applied to derive an allowable ambient air concentration of 1 μg Hg/m^3 (U.S. EPA, 1984d). For the purposes of this methodology, however, TBI should be an estimate of background exposure from all sources, including inhalation.

As stated in the beginning of this subsection, the TBI is the summed estimate of all possible background exposures, except exposures resulting from a sludge disposal practice. To be more exact, the TBI should be a summed total of all toxicologically effective intakes from all nonsludge exposures. To determine the effective TBI, background intake values (BI) for each exposure route must be divided by that route's particular relative effectiveness (RE) factor. Thus, the TBI can be mathematically derived after all the background exposures have been determined, using the following equation:

$$\text{TBI (mg/day)} = \frac{\text{BI (food)}}{\text{RE (food)}} + \frac{\text{BI (water)}}{\text{RE (water)}} + \frac{\text{BI (air)}}{\text{RE (air)}} + \cdots + \frac{\text{BI (n)}}{\text{RE (n)}} \qquad (8\text{-}20)$$

where:

TBI = total background intake rate of pollutant from all other sources of exposure (mg/day)

BI = background intake of pollutant from a given exposure route, indicated by subscript (mg/day)

RE = relative effectiveness, with respect to inhalation exposure, of the exposure route indicated by subscript (unitless)

8.4.3.1.4. Fraction of Inhaled Air from Contaminated Area -- It is recognized that an individual exposed to air emissions from a sludge application site may not necessarily remain in the application proximity for 24 hours/day. However, if it is assumed that residential areas may be contaminated, it is likely that less mobile individuals will include those at greatest risk. Therefore, it is reasonable to assume that 100% of the air breathed by the most exposed individuals will be from the area of the sludge application site.

8.4.3.1.5. Relative Effectiveness of Exposure (RE) -- RE is a unitless factor that shows the relative toxicological effectiveness of an exposure by a given route when compared with another route. The value of RE may reflect observed or estimated differences in absorption between the inhalation and ingestion routes, which can then significantly influence the quality of a chemical that reaches a particular target tissue, the length of time it takes to get there, and the degree and duration of the effect. The RE factor may also reflect differences in the occurrence of critical toxicological effects at the portal of entry. For example, carbon tetrachloride and chloroform were estimated to be 40 and 65% as effective, respectively, by inhalation as by ingestion based on high-dose absorption differences (U.S. EPA, 1984e,f). In addition to route differences, RE can reflect differences in bioavailability due to the exposure matrix. For example, absorption of nickel ingested in water has been estimated to be 5 times that of nickel ingested in the diet (U.S. EPA, 1985d). The presence of food in the gastrointestinal tract may delay absorption and reduce the availability of orally administered compounds, as demonstrated for halocarbons (NRC, 1986).

Physiologically based pharmacokinetic (PB-PK) models have evolved into particularly useful tools for predicting disposition differences due to exposure route differences. Their use is predicated on the premise that an effective (target-tissue) dose achieved by one route in a particular species is expected to be equally effective when achieved by another exposure route or in some other species. For example, the proper measure of target-tissue dose for a chemical with pharmacologic activity would be the tissue concentration divided by some measure of the receptor binding constant for that chemical. Such models account for fundamental physiologic and biochemical parameters such as blood flows, ventilatory parameters, metabolic capacities and renal clearance, tailored by the physicochemical and biochemical properties of the agent in question. The behavior of a substance administered by a different exposure route can be determined by adding equations that describe the nature of the new input function. Similarly, since known physiologic parameters are used, different species (e.g., humans vs. test species) can be modeled by replacing the appropriate constants. It should be emphasized that PB-PK models must be used in conjunction with toxicity and mechanistic studies in order to relate the effective dose associated with a certain level of risk for the test species and conditions to other scenarios. A detailed approach for the application of PB-PK models for derivation of the RE factor is beyond the scope of this document, but the reader is referred to the comprehensive discussion in NRC (1986). Other useful discussions on considerations necessary when extrapolating route-to-route are found in Pepelko and Withey (1985) and Clewell and Andersen (1985).

Since exposure for the vapor pathway is by inhalation, all the RE factors are applied with respect to the inhalation route. Therefore, the value of RE in Equation 8-19 gives the relative effectiveness of the exposure route and matrix on which the RfD was based when compared with inhalation of contaminated air. Similarly, the RE factors in Equation 8-20 show the relative effectiveness, with respect to the inhalation route, of each background exposure route and matrix.

An RE factor should only be applied where well documented/referenced information is available on the contaminant's observed relative effectiveness or its pharmacokinetics. When such information is not available, RE is equal to 1.

8.4.3.2. CARCINOGENS -- For carcinogenic chemicals, the Agency considers the excess risk of cancer to be linearly related to dose (except at high dose levels) (Federal Register, 1986a). The threshold assumption, therefore, does not hold, as risk diminishes with dose but does not become zero or background until dose becomes zero.

The decision whether to treat a chemical as a threshold- or non-threshold-acting (carcinogenic) agent depends on the weight of the evidence that it may be carcinogenic to humans. Methods for classifying chemicals as to their weight of evidence have been described by U.S. EPA (Federal Register, 1986a), and most of the chemicals that currently are candidates for sludge criteria have recently been classified in Health Assessment Documents or other reports prepared by the U.S. EPA's Office of Health and Environmental Assessment (OHEA), or in connection with the development of RMCLs for drinking water contaminants (Federal Register, 1985). To derive values of RAC, a decision must be made as to which classifications constitute sufficient evidence for basing a quantitative risk assessment on a presumption of carcinogenicity. Chemicals in classifications A and B, "human carcinogen" and "probable human carcinogen," respectively, have usually been assessed as carcinogens, whereas those in classifications D and E, "not classifiable as to human carcinogenicity because of inadequate human and animal data" and "evidence of noncarcinogenicity for humans," respectively, have usually been assessed according to threshold effects. Chemicals classified as C, "possible human carcinogen," have received varying treatment. For example, lindane, classified by the Carcinogen Assessment Group (CAG) of the U.S. EPA as "B2-C," or between the lower range of the B category and category C, has been assessed both using the linear model for tumorigenic effects (U.S. EPA, 1980b) and based on threshold effects (Federal Register, 1985). Table 8-4 gives an illustration of these U.S. EPA classifications based on the available weight of evidence.

The use of the weight-of-evidence classification without noting the explanatory material for a specific chemical may lead to a flawed conclusion, since some of the classifications are exposure route dependent. Certain compounds (such as nickel) have been shown to be carcinogenic by the inhalation route but not by ingestion. The issue of whether or not to treat an agent as carcinogenic by ingestion remains controversial for several chemicals.

If a pollutant is to be assessed according to nonthreshold, carcinogenic effects, the reference concentration in air, RAC, is derived as follows:

$$\text{Reference Air Concentration: } RAC = \left[\left(\frac{RL \times bw}{q_1{}^* \times RE}\right) - TBI\right] \div I_a \qquad (8\text{-}21)$$

where:

$q_1{}^*$ = human cancer potency ($[mg/kg/day]^{-1}$)
RL = risk level (unitless) (10^{-5}, 10^{-6}, etc.)
bw = human body weight (kg)
RE = relative effectiveness of inhalation exposure (unitless)
I_a = air inhalation rate (m^3/day)
TBI = total background intake rate of pollutant (mg/day); from all other sources of exposure

The RAC, in the case of carcinogens, is thought to be protective since the $q_1{}^*$ is typically an upper limit value (the true potency is considered unlikely to be greater and may be less). The definition and derivation of each of the parameters used to estimate RAC for carcinogens are further discussed below.

8.4.3.2.1. **Human Cancer Potency ($q_1{}^*$)** -- For most carcinogenic chemicals, the linearized multistage model is recommended for estimating human cancer potency from animal data (Federal Register, 1986a). When epidemiological data are available, potency is estimated based on the observed

TABLE 8-4

Illustrative Categorization of Carcinogenic Evidence Based on Animal and Human Data*

Human Evidence	Animal Evidence				
	Sufficient	Limited	Inadequate	No Data	No Evidence
Sufficient	A	A	A	A	A
Limited	B1	B1	B1	B1	B1
Inadequate	B2	C	D	D	D
No data	B2	C	D	D	E
No evidence	B2	C	D	D	E

*The above assignments are presented for illustrative purposes. There may be nuances in the classification of both animal and human data indicating that different categorizations than those given in the table should be assigned. Furthermore, these assignments are tentative and may be modified by ancillary evidence. In this regard all relevant information should be evaluated to determine if the designation of the overall weight of evidence needs to be modified. Relevant factors to be included along with the tumor data from human and animal studies include structure-activity relationships, short-term test findings, results of appropriate physiological, biochemical and toxicological observations, and comparative metabolism and pharmacokinetic studies. The nature of these findings may cause an adjustment of the overall categorization of the weight of evidence.

relative risk in exposed vs. nonexposed individuals, and on the magnitude of exposure. Guidelines for use of these procedures have been presented in the Federal Register (1980, 1985) and in each of a series of Health Assessment Documents prepared by OHEA (such as U.S. EPA, 1985c). The true potency value is considered unlikely to be above the upper-bound estimate of the slope of the dose-response curve in the low-dose range, and it is expressed in terms of risk-per-dose, where dose is in units of mg/kg/day. Thus, q_1* has units of $(mg/kg/day)^{-1}$. OHEA has derived potency estimates for each of the potentially carcinogenic chemicals that presently are candidates for sludge criteria. Therefore, no new effort will be required to develop potency estimates to derive sludge criteria.

8.4.3.2.2. Risk Level (RL) -- Since by definition no "safe" level exists for exposure to nonthreshold agents, values of RAC are calculated to reflect various levels of cancer risk. If RL is set at zero, then RAC will be zero. If RL is set at 10^{-6}, RAC will be the concentration that, for lifetime exposure, is calculated to have an upper-bound cancer risk of one case in one million individuals exposed. This risk level refers to excess cancer risk, that is, over and above the background cancer risk in unexposed individuals. By varying RL, RAC may be calculated for any level of risk in the low-dose region, RL $\leq 10^{-2}$. Specification of a given risk level on which to base regulations is a matter of policy. Therefore, it is common practice to derive criteria representing several levels of risk without specifying any level as "acceptable."

8.4.3.2.3. Human Body Weight (bw) and Air Inhalation Rate (I_a) -- Considerations for defining bw and I_a are similar to those stated in Section 8.4.3.1.2. The CAG assumes respective values of 70 kg and 20 m^3/day to derive unit risk estimates for inhalation, which are potency estimates transformed to units of $(\mu g/m^3)^{-1}$. As illustrated in Table 8-3, exposures may be higher in children than in adults when the ratios of inhalation volumes to body weights are compared. However, exposure is lifelong, and therefore values of bw and I_a are usually chosen to be representative of adults.

8.4.3.2.4. Relative Effectiveness of Exposure (RE) -- Considerations for defining RE for Equation 8-21 are the same as described previously in Section 8.4.3.1.5.

8.4.3.2.5. Total Background Intake Rate of Pollutant (TBI) -- It is important to recognize that sources of exposure other than the sludge disposal practice may exist, and that the total exposure should be maintained below the determined cancer risk-specific exposure level. Procedures for determining TBI are as described previously in Section 8.4.3.1.3.

8.4.3.2.6. Fraction of Inhaled Air from Contaminated Area -- As for threshold-acting agents (see Section 8.4.3.1.4.), it is assumed for carcinogens that 100% of the air breathed by the most exposed individuals will be from the area of landfill.

8.5. EXAMPLE CALCULATIONS

8.5.1. Site-Specific Application. This section presents sample calculations for determining the vapor exposure resulting from land application of sludge. In the following, calculations are first made for a particular land application site on a site-specific application and then an example is given for calculating maximum allowable contaminant levels in sludge. Benzene, because it is a volatile contaminant of concern, is used for the example calculations. For the examples, data describing the occurrence and concentration of benzene in sludge are taken from U.S. EPA (1985a). The pathway and chemical parameters used in the calculations are summarized in Table 8-5.

TABLE 8-5

Input Parameters for Example Calculations: Vapor Loss

Fate and Transport: Pathway Data		
1.	Vertical Term for Transport	$V = 1$
2.	Lateral Virtual Distance	$X_y = 2840$ m
3.	Average Wind Speed	$\nu = 2$ m/sec
4.	Length or Width of Source	$X_o = 1000$ m
5.	Distance from Center of Source to Receptor	$r' = 600$ m
6.	Standard Deviation of the Vertical Concentration Distance	$\alpha_z = 9.75$ m
7.	Annual Sludge Application Rate	$AR_a = 50$ Mg DW/ha-year
8.	Sludge Solids Content	$S = 0.06$ kg/kg
Fate and Transport: Chemical-Specific Data - Benzene		
1.	Contaminant Concentration in Sludge	$SC = 6.58$ mg/kg DW
2.	Henry's Law Constant	$H_i = 0.24$ (unitless)
Health Effects Data (Benzene)		
1.	Reference Air Concentration	$RAC = 0.12\ \mu g/m^3$
2.	NIOSH Recommended Exposure Limit (60-minute ceiling)	$NREL = 3.2\ mg/m^3$ (1 ppm)*
3.	OSHA Standard (8-hour time-weighted average)	$OS = 32\ mg/m^3$ (10 ppm)*

*Source: CDC, 1983

Data describing waste sites are values assumed to represent reasonable cases. In actual practice, the data used in the calculations would be those measured or collected by the applicant.

8.5.1.1. **TIER 1 CALCULATION** -- The Tier 1 calculation involves comparing the equilibrium vapor concentration of the constituent with the RAC. This approach represents the worst possible case with no allowance made for atmospheric dilution, dispersion or degradation. The equilibrium vapor concentration is taken as the product of the Henry's Law Constant of the constituent and the liquid phase concentration of the constituent.

The liquid phase constituent concentration can be obtained in several ways. If the leachate extraction procedure is used, the liquid concentration will be determined directly from the procedure. If the analytical results are expressed in terms of dry weight, it will be necessary to convert the dry weight results to an equivalent liquid phase concentration accounting for partitioning between the liquid and solid phases. This is accomplished by rearranging Equation 8-6 as follows:

$$C_l = \frac{(SC)(S)}{(K_{oc})(f_{oc})(S) + \frac{(1-S)}{\gamma_\ell}} \qquad (8\text{-}22)$$

where:

C_l = concentration of contaminant in sludge liquid (mg/ℓ)

SC = dry weight concentration of contaminant in sludge (mg/kg)

S = solids content of sludge (kg dry solids/kg total wet sludge)

K_{oc} = organic carbon distribution coefficient

$$\frac{\text{mg contaminant/kg organic carbon}}{\text{mg contaminant/}\ell\text{ sludge liquid}}$$

f_{oc} = organic carbon content of sludge (kg organic carbon/kg sludge solids)

γ_ℓ = density of sludge liquid (kg sludge liquid/ℓ sludge liquid)

For the example calculation, the 95th percentile dry weight concentration of benzene in sludge, 6.58 mg/kg, reported in U.S. EPA (1985a) was used. The organic carbon distribution coefficient for benzene is 74.2 ℓ/kg (U.S. EPA, 1985a). Assuming a solids content of 6% for digested sludge (see Table 7-2), an organic carbon content of 50% for the sludge solids, and a density of 1 kg/ℓ for the sludge liquid, the equivalent liquid concentration is the following:

$$C_1 = \frac{(6.58\ \text{mg/kg})(0.06\ \text{kg/kg})}{(74.2\ \ell/\text{kg})(0.5\ \text{kg/kg})(0.06\ \text{kg/kg}) + \frac{(1-0.06)\ \text{kg/kg}}{1.0\ \text{kg}/\ell}}$$

$$= 0.125\ \text{mg}/\ell$$

The Henry's Law Constant for benzene is then used to calculate the vapor concentration in equilibrium with the liquid concentration:

$$Cv_i = H_i C_1 \qquad (8\text{-}23)$$

From Appendix C of the Landfill Methodology Document (U.S. EPA, 1986), the dimensionless Henry's Law Constant for benzene is 0.24. The equilibrium vapor pressure is

$$Cv_i = (0.24)\ (0.125\ \text{mg}/\ell) = 0.030\ \text{mg}/\ell = 30\ \text{mg/m}^3$$

The resulting value for Cv_i of 30 mg/m^3 does not exceed the OSHA standard of 32 mg/m^3 (10 ppm), which is an 8-hour time-weighted average exposure limit. However, it does exceed the more restrictive NIOSH recommendation of 3.2 mg/m^3 (1 ppm) as a 60-minute ceiling (see Table 8-5). Therefore, this exposure level, which might only occur under worst-case atmospheric conditions, could arguably pose a hazard to workers in the field following application.

To use this result for screening purposes, Cv_i is compared with the RAC. The RAC for the carcinogen benzene is derived using Equation 8-21:

$$RAC = \left[\left(\frac{RL \times bw}{q_1^* \times RE}\right) - TBI\right] \div I_a$$

The risk level (RL), the body weight (bw) and the daily inhalation volume (I_a) are set for this example at 10^{-6}, 70 kg and 20 m^3, respectively. The human cancer potency for oral exposure to benzene has been determined by the U.S. EPA to be 2.9×10^{-2} $(mg/kg/day)^{-1}$ (U.S. EPA, 1985a). The relative effectiveness factor (RE) is set at 1.0. Current total background intake (TBI) of benzene from all other sources (except from land application of sludges) has not been determined for 1986, but for illustrative purposes a TBI of 0 is used here to derive an example RAC. Determination of an RAC for a specific landfill site should be based on a current local assessment of TBI.

$$RAC = \left[\left(\frac{10^{-6} \times 70 \text{ kg}}{2.9 \times 10^{-2} \text{ (mg/kg/day)}^{-1} \times 1.0}\right) - 0\right] \div 20 \text{ m}^3$$

$$= 1.2 \times 10^{-4} \text{ mg/m}^3$$

$$= 0.12 \text{ }\mu\text{g/m}^3$$

The above vapor concentration is then compared with the reference value for benzene, RAC = 0.12 $\mu g/m^3$. Since 30 mg/m^3 >> 0.12 $\mu g/m^3$, it is necessary to proceed to Tier 2.

8.5.1.2. TIER 2 CALCULATION -- The Tier 2 methodology involves estimating the flux of contaminant out of the land application site and using an atmospheric dispersion model to predict the atmospheric concentration of contaminant downwind of the site. The long-term average downwind concentration is then compared with the reference air concentration.

For Tier 2, the annual average flux is calculated from the mass of contaminant added annually per unit area (RP_a). This is done by taking the product of the sludge concentration (SC) for the contaminant and the annualized sludge application rate (AR_a):

$$RP_a = (6.58 \text{ mg/kg}) (50 \text{ Mg/ha-year}) \times 10^{-3}$$

$$= 0.329 \text{ kg/ha-year}$$

The flux to the atmosphere (Q_v, in g/m^2-sec) is found by dividing RP_a by 3.2×10^8 (from Equation 8-7):

$$Q_V = \frac{0.329 \text{ kg/ha-year}}{3.2\times10^8 \text{ kg-m}^2\text{-sec/g-ha-year}}$$

$$= 1.03\times10^{-9} \text{ g/m}^2\text{-sec}$$

The source-receptor ratio (SRR) is calculated as the ratio of the product of 2.032, the site width (X_o) squared, and the vertical term (V) to the product of the sum of the distance from source center to receptor (r') and the lateral virtual distance (X_y), the mean wind speed (ν), and the standard deviation of the vertical concentration distribution (σz) (Equation 8-9):

$$SRR = (2.032)\left[\frac{(1000 \text{ m})^2 \times 1}{(600 \text{ m} + 2840 \text{ m})(2 \text{ m/sec})(9.75 \text{ m})}\right]$$

$$= 30.29 \text{ (sec/m)}$$

The predicted concentration (C_c) at the compliance point (such as the property boundary) is calculated as the product of the converted flux (Q_v) and the source-receptor ratio (SRR) (Equation 8-8):

$$C_c = (1.03\times10^{-9} \text{ g/m}^2\text{-sec})\ (30.29 \text{ sec/m})$$

$$= 31.2\times10^{-9} \text{ g/m}^3$$

$$= 31.2 \text{ ng/m}^3$$

This concentration is compared with the RAC of 0.12 μg/m^3 (120 ng/m^3). In this case, the predicted concentration is about a factor of 4 smaller than the RAC. As a consequence, no inhalation hazards from benzene are likely to occur.

8.5.2. **National Criteria.** To set maximum sludge concentration criteria, it is necessary to apply the methodology in reverse. In the following example, this is done using the example case in Table 8-5 as the representative scenario. The approach utilizes Equation 8-17 and the SRR calculated for the site according to the following.

From Equation 8-9, the SRR is calculated for the site as the ratio of the product of 2.032, the site width squared (X_o), and the vertical term (V) to the product of the sum of the distance from the source center to the receptor (r') and the virtual lateral distance (X_y), the mean wind speed (υ), and the standard deviation of the vertical concentration distribution (σz).

$$\text{SRR} = (2.032)\left[\frac{(1000\ \text{m})^2 \times 1}{(600\ \text{m} + 2840\ \text{m})(2\ \text{m/sec})(9.75\ \text{m})}\right]$$

$$= 30.29\ (\text{sec/m})$$

The reference sludge concentration is then calculated as the ratio of the product of RAC and $3.2\text{x}10^8$, to the product of the SRR and the sludge application rate (AR_a).

$$\text{RSC} = \frac{(1.2\text{x}10^{-4}\ \text{mg/m}^3)\ (3.2\text{x}10^5\ \text{kg-m}^2\text{-sec/mg-ha-year})}{(30.29\ \text{sec/m})\ (50\ \text{Mg/ha-year})\ (10^{-3}\ \text{kg-kg/Mg-mg})}$$

$$= 25.5\ \text{mg/kg}$$

Hence, it would take nearly four times the 95th percentile concentration of benzene in sludge (6.58 mg/kg) to exceed inhalation limits at the property boundary.

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APPENDIX 1

REANALYSIS OF THE FDA REVISED TOTAL DIET FOOD LIST

TABLE A1-1*

Reanalysis of FDA Revised Total Diet Food List: Item Number, Item Name, Food Category, Comments, Fractional Composition (by fresh weight of item or recipe) and Percent Dry Matter of Each Component. Sorted by Item Number.

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*Refer to the text of Section 4.1.4. for discussion of the purposes and methods for this reanalysis.

Table A1-1

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM
001	whole milk, fluid	dairy		0.97	0.08
001	whole milk, fluid	dairy fat	3.3% fat	0.03	1.00
002	low-fat milk 2% fat, fluid	dairy		0.98	0.08
002	low-fat milk 2% fat, fluid	dairy fat		0.02	1.00
003	chocolate milk, fluid, low-fat milk	dairy		0.92	0.08
003	chocolate milk, fluid, low-fat milk	other	sugar, cocoa, etc.	0.06	0.99
003	chocolate milk, fluid, low-fat milk	dairy fat	2.0% fat	0.02	1.00
004	skim milk, fluid	dairy		1.00	0.09
005	buttermilk, fluid	dairy		0.99	0.08
005	buttermilk, fluid	dairy fat	1.0% fat	0.01	1.00
006	yogurt, plain, low-fat	dairy	with added milk solids	0.98	0.13
006	yogurt, plain, low-fat	dairy fat		0.02	1.00
007	milkshake, chocolate, fast-food type	dairy		0.79	0.12
007	milkshake, chocolate, fast-food type	other	sugar, syrups, fillers	0.19	0.97
007	milkshake, chocolate, fast-food type	dairy fat		0.02	1.00
008	evaporated milk, canned	dairy		0.92	0.18
008	evaporated milk, canned	dairy fat		0.08	1.00
009	yogurt, sweetened, strawberry, pre-stirred	dairy	low-fat milk	0.86	0.08
009	yogurt, sweetened, strawberry, pre-stirred	other	sugar	0.09	0.99
009	yogurt, sweetened, strawberry, pre-stirred	other	fruit	0.04	0.78
009	yogurt, sweetened, strawberry, pre-stirred	dairy fat		0.01	1.00
010	cheese, American, processed	dairy		0.68	0.35
010	cheese, American, processed	dairy fat		0.32	1.00
011	cottage cheese, creamed, 4% milkfat	dairy		0.96	0.16
011	cottage cheese, creamed, 4% milkfat	dairy fat		0.04	1.00
012	cheese, Cheddar, (sharp/mild)	dairy		0.68	0.40
012	cheese, Cheddar, (sharp/mild)	dairy fat		0.32	1.00
013	beef, ground, regular hamburger, cooked in patty shape	beef		0.80	0.46
013	beef, ground, regular hamburger, cooked in patty shape	beef fat		0.20	1.00
014	beef chuck roast, oven roasted	beef		0.85	0.38
014	beef chuck roast, oven roasted	beef fat		0.15	1.00
015	beef, round steak, stewed in water	beef		0.85	0.39
015	beef, round steak, stewed in water	beef fat		0.15	1.00
016	beef (loin/sirloin) steak, pan cooked with added fat	beef		0.70	0.26
016	beef (loin/sirloin) steak, pan cooked with added fat	beef fat	assume not trimmed	0.26	1.00
016	beef (loin/sirloin) steak, pan cooked with added fat	veg oil		0.04	1.00
017	pork, ham, cured, not canned, oven cooked	pork		0.78	0.46
017	pork, ham, cured, not canned, oven cooked	pork fat		0.22	1.00
018	pork chop, pan cooked with added fat	pork		0.70	0.35
018	pork chop, pan cooked with added fat	pork fat	assume not trimmed	0.26	1.00
018	pork chop, pan cooked with added fat	veg oil		0.04	1.00
019	pork sausage, (link/bulk), oven cooked	pork		0.54	0.35
019	pork sausage, (link/bulk), oven cooked	pork fat		0.46	1.00
020	pork, bacon, oven cooked	pork fat		0.53	1.00
020	pork, bacon, oven cooked	pork		0.47	0.77
021	pork roast, loin, oven cooked	pork		0.68	0.47
021	pork roast, loin, oven cooked	pork fat		0.32	1.00
022	lamb chop, pan cooked with added fat	lamb		0.71	0.34
022	lamb chop, pan cooked with added fat	lamb fat	assume not trimmed	0.25	1.00
022	lamb chop, pan cooked with added fat	veg oil		0.04	1.00
023	veal cutlet, breaded, pan cooked with added fat	beef		0.42	0.15
023	veal cutlet, breaded, pan cooked with added fat	egg		0.20	0.25
023	veal cutlet, breaded, pan cooked with added fat	wheat		0.20	0.88
023	veal cutlet, breaded, pan cooked with added fat	veg oil		0.10	1.00
023	veal cutlet, breaded, pan cooked with added fat	beef fat		0.08	1.00

Table A1-1

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM
024	chicken,drumstk/breast,breaded,fried w/add.fat,hommmade	poultry		0.77	0.38
024	chicken,drumstk/breast,breaded,fried w/add.fat,hommmade	veg oil		0.13	1.00
024	chicken,drumstk/breast,breaded,fried w/add.fat,hommmade	poultry fat		0.06	1.00
024	chicken,drumstk/breast,breaded,fried w/add.fat,hommmade	wheat		0.04	0.88
025	chicken, oven roasted	poultry		0.96	0.29
025	chicken, oven roasted	poultry fat		0.04	1.00
026	turkey breast, oven roasted	poultry		0.96	0.38
026	turkey breast, oven roasted	poultry fat		0.04	1.00
027	liver (beef/calf), pan fried with added fat	beef liver		0.89	0.37
027	liver (beef/calf), pan fried with added fat	beef liver fat		0.09	1.00
027	liver (beef/calf), pan fried with added fat	veg oil		0.02	1.00
028	frankfurters, (beef/beef and pork), boiled	beef	assume beef	0.71	0.18
028	frankfurters, (beef/beef and pork), boiled	beef fat	assume beef	0.27	1.00
028	frankfurters, (beef/beef and pork), boiled	other	fillers, sugar	0.02	1.00
029	bologna	pork		0.71	0.16
029	bologna	pork fat		0.29	1.00
030	salami, lunch meat type, regular, not hard	pork		0.75	0.26
030	salami, lunch meat type, regular, not hard	pork fat		0.25	1.00
031	(cod/haddock) fillet, (fresh/frozen), oven cooked	fish	haddock, fresh	1.00	0.24
032	tuna, canned in oil, drained	fish		0.92	0.32
032	tuna, canned in oil, drained	veg oil		0.08	1.00
033	shrimp(fresh/frozen),breaded&fried w/add. fat,hommmade	fish		0.74	0.20
033	shrimp(fresh/frozen),breaded&fried w/add. fat,hommmade	wheat		0.10	0.88
033	shrimp(fresh/frozen),breaded&fried w/add. fat,hommmade	veg oil		0.06	1.00
033	shrimp(fresh/frozen),breaded&fried w/add. fat,hommmade	egg		0.05	0.25
033	shrimp(fresh/frozen),breaded&fried w/add. fat,hommmade	other	sugar	0.03	0.99
033	shrimp(fresh/frozen),breaded&fried w/add. fat,hommmade	fish	fish fat	0.02	1.00
034	fish sticks, commercial, frozen, oven cooked	fish		0.63	0.28
034	fish sticks, commercial, frozen, oven cooked	wheat		0.26	0.88
034	fish sticks, commercial, frozen, oven cooked	veg oil		0.11	1.00
035	eggs, scrambled with added milk and fat	egg		0.76	0.25
035	eggs, scrambled with added milk and fat	dairy	assume whole milk	0.20	0.08
035	eggs, scrambled with added milk and fat	veg oil	margarine	0.03	1.00
035	eggs, scrambled with added milk and fat	dairy fat	assume whole milk	0.01	1.00
036	eggs, fried with added fat	egg		0.94	0.25
036	eggs, fried with added fat	veg oil		0.06	1.00
037	eggs, soft boiled	egg	hard cooked, shell removed	1.00	0.24
038	pinto beans, boiled from dried	legume veg		1.00	0.34
039	pork and beans, canned	garden fruit	tomato	0.40	0.06
039	pork and beans, canned	legume veg		0.40	0.31
039	pork and beans, canned	corn	corn syrup	0.07	0.99
039	pork and beans, canned	pork		0.06	0.15
039	pork and beans, canned	corn	starch	0.04	0.99
039	pork and beans, canned	pork fat		0.03	1.00
040	cowpeas (blackeyed peas), boiled from dried	legume veg	drained	1.00	0.28
041	lima beans, mature, boiled from dried	legume veg		1.00	0.34
042	lima beans, immature, frozen, boiled	legume veg		1.00	0.26
043	navy beans, boiled from dried	legume veg		1.00	0.31
044	red beans, boiled from dried	legume veg		1.00	0.31
045	peas, green, canned	legume veg	whole, drained	1.00	0.23
046	peas, green, frozen, boiled	legume veg	drained	1.00	0.18
047	peanut butter, creamy, commercial in jar	peanuts		0.50	0.98
047	peanut butter, creamy, commercial in jar	other	sugar, corn syrup	0.31	1.00
047	peanut butter, creamy, commercial in jar	peanuts	peanut oil	0.19	0.99
048	peanuts, dry roasted in jar, salted	peanuts		1.00	0.98
049	pecans, packaged, unsalted	other		1.00	0.97

Table A1-1

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM
050	rice, white, enriched, cooked	rice		1.00	0.27
051	oatmeal, cooked	oats		1.00	0.13
052	farina, enriched, cooked	wheat	quick-cooking	1.00	0.11
053	corn grits(hominy grits), enriched, cooked	corn	degermed	1.00	0.13
054	corn, (fresh/frozen), boiled	corn	fresh, 5" by 1 3/4" ear	1.00	0.26
055	corn, canned	corn	wet packed, drain solids	1.00	0.24
056	corn, cream style, canned	corn		1.00	0.24
057	popcorn, popped in oil	corn	large kernal, salt added	0.78	0.94
057	popcorn, popped in oil	veg oil	coconut oil	0.22	1.00
058	whitebread, enriched	water		0.37	0.00
058	whitebread, enriched	wheat		0.35	0.88
058	whitebread, enriched	other	sugar, corn syrup	0.26	0.73
058	whitebread, enriched	veg oil		0.02	1.00
059	rolls, white, soft, enriched	wheat		0.72	0.88
059	rolls, white, soft, enriched	other		0.23	0.99
059	rolls, white, soft, enriched	veg oil		0.05	1.00
060	cornbread, southern style, homemade	corn	corn meal	0.31	0.89
060	cornbread, southern style, homemade	dairy		0.29	0.08
060	cornbread, southern style, homemade	wheat		0.14	0.88
060	cornbread, southern style, homemade	egg		0.13	0.25
060	cornbread, southern style, homemade	other	sugar	0.06	0.99
060	cornbread, southern style, homemade	veg oil		0.06	1.00
060	cornbread, southern style, homemade	dairy fat		0.01	1.00
061	biscuits, baking powder, enriched, refrigerated type, baked	wheat		0.40	0.88
061	biscuits, baking powder, enriched, refrigerated type, baked	water		0.28	0.00
061	biscuits, baking powder, enriched, refrigerated type, baked	other	sugar, corn syrup	0.24	0.73
061	biscuits, baking powder, enriched, refrigerated type, baked	veg oil		0.08	1.00
062	whole wheat bread	wheat		0.36	0.88
062	whole wheat bread	water		0.31	0.00
062	whole wheat bread	other	sugar, syrups	0.30	0.99
062	whole wheat bread	veg oil		0.03	1.00
063	tortilla, flour	corn	yellow, untreated	1.00	0.88
064	rye bread	water		0.37	0.00
064	rye bread	wheat	2/3 wheat flour	0.24	0.88
064	rye bread	other	sugar, corn syrup	0.23	0.73
064	rye bread	other grain	1/3 rye flour	0.12	0.88
064	rye bread	veg oil		0.04	1.00
065	muffins (blueberry/plain)	wheat		0.47	0.88
065	muffins (blueberry/plain)	veg oil		0.14	1.00
065	muffins (blueberry/plain)	other	sugar	0.13	0.99
065	muffins (blueberry/plain)	dairy		0.11	0.08
065	muffins (blueberry/plain)	other	blueberry	0.08	0.15
065	muffins (blueberry/plain)	egg		0.04	0.25
065	muffins (blueberry/plain)	dairy fat		0.03	1.00
066	saltine crackers	wheat	enriched flour	0.90	0.88
066	saltine crackers	veg oil		0.10	1.00
067	corn chips	corn		0.80	0.95
067	corn chips	veg oil		0.20	1.00
068	pancakes made from mix w/addition of egg, milk and oil	egg		0.35	0.40
068	pancakes made from mix w/addition of egg, milk and oil	dairy	whole milk	0.32	0.31
068	pancakes made from mix w/addition of egg, milk and oil	wheat		0.19	0.90
068	pancakes made from mix w/addition of egg, milk and oil	veg oil		0.08	1.00
068	pancakes made from mix w/addition of egg, milk and oil	corn		0.04	0.90
068	pancakes made from mix w/addition of egg, milk and oil	dairy fat		0.02	1.00
069	noodles, egg, enriched, cooked	water		0.61	0.00
069	noodles, egg, enriched, cooked	wheat		0.34	0.88

Table A1-1

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM
069	noodles, egg, enriched, cooked	egg		0.05	0.25
070	macaroni, enriched, cooked	wheat	tender stage	1.00	0.27
071	corn flakes	corn		1.00	0.96
072	fruit flavored, presweetened cereal	corn	assume Fruit Loops	0.81	0.99
072	fruit flavored, presweetened cereal	other	sugar,salt,iron,vitamins	0.19	0.98
073	Shredded Wheat cereal	wheat		1.00	0.93
074	Raisin Bran cereal	wheat	assume no sugar on raisins	0.57	0.97
074	Raisin Bran cereal	other	raisins	0.22	0.82
074	Raisin Bran cereal	other	sugar	0.21	0.99
075	crisped rice cereal	rice		0.71	0.88
075	crisped rice cereal	other	sugar	0.29	0.99
076	granola, with raisins	oats		0.61	0.88
076	granola, with raisins	other	raisins	0.26	0.82
076	granola, with raisins	other	sugar	0.13	0.99
077	oat ring. unsweetened cereal	oats		0.50	0.88
077	oat ring. unsweetened cereal	corn	corn meal	0.45	0.98
077	oat ring. unsweetened cereal	other	sugar	0.05	0.99
078	apple, red with peel, raw	other	fruit	1.00	0.16
079	orange, raw, (navel/Valencia)	other	fruit	1.00	0.14
080	banana, raw	other	fruit	1.00	0.24
081	watermelon, raw	other	fruit	1.00	0.07
082	peach, canned in heavy syrup	other	sugar, syrup, etc.	0.56	0.27
082	peach, canned in heavy syrup	other	fruit	0.44	0.09
083	peach, raw	other	fruit	1.00	0.11
084	applesauce, canned, sweetened	other	sugar	0.56	0.00
084	applesauce, canned, sweetened	other	fruit	0.44	0.11
085	pear, raw	other	fruit	1.00	0.17
086	strawberries, raw	other	fruit	1.00	0.10
087	fruit cocktail, canned in heavy syrup	other	sugar, syrup, etc.	0.56	0.27
087	fruit cocktail, canned in heavy syrup	other	fruit	0.44	0.09
088	grapes (purple/green), raw	other	fruit	1.00	0.19
089	cantaloupe, raw	other	fruit with rind	1.00	0.09
090	pear, canned in heavy syrup	other	sugar, syrup, etc.	0.56	0.27
090	pear, canned in heavy syrup	other	fruit	0.44	0.09
091	plums, pruple, raw	other	fruit, Japanese & hybrid	1.00	0.13
092	grapefruit, raw	other	fruit	1.00	0.11
093	pineapple, canned in juice pack	other	fruit, includes fruit pack juices	1.00	0.15
094	cherries, sweet, raw	other	fruit	1.00	0.20
095	raisins, dried	other	fruit	1.00	0.82
096	prunes, dried, uncooked	other	fruit	1.00	0.72
097	avocado, raw	garden fruit		0.93	0.16
097	avocado, raw	garden fruit	avocado oil	0.07	1.00
098	orange juice, frozen, reconstituted	other	fruit, 3 parts water	1.00	0.13
099	apple juice, canned, unsweetened	other	fruit	1.00	0.12
100	grapefruit juice, frozen, reconstituted	other	fruit, 3 parts water	1.00	0.11
101	grape juice, canned	other	fruit	1.00	0.17
102	pineapple juice, canned	other	fruit, unsweetened	1.00	0.14
103	prune juice, bottled	other	fruit	1.00	0.20
104	orange drink with added vitamin C, canned	other	fruit, sugar, water	1.00	0.10
105	lemonade, frozen, reconstituted	other	fruit, 4 1/3 parts water	1.00	0.11
106	spinach, canned	leafy veg	drained	1.00	0.09
107	spinach, (fresh/frozen), boiled	leafy veg	fresh	1.00	0.08
108	collards, (fresh/frozen), boiled	leafy veg	fresh, leaves without stems	1.00	0.10
109	lettuce, raw	leafy veg	Iceberg lettuce	1.00	0.04
110	cabbage, boiled from raw	leafy veg		1.00	0.06
111	coleslaw with dressing, homemade	leafy veg	1/2 tsp celery seed added	0.50	0.08

Table A1-1

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM
111	coleslaw with dressing, homemade	egg	mayonnaise	0.22	0.25
111	coleslaw with dressing, homemade	other	sugar	0.18	0.99
111	coleslaw with dressing, homemade	veg oil	mayonnaise	0.08	1.00
111	coleslaw with dressing, homemade	other	vinegar	0.02	0.04
112	sauerkraut, canned	leafy veg	solids & liquids	1.00	0.07
113	broccoli, (fresh/frozen), boiled	leafy veg		1.00	0.09
114	celery, raw	leafy veg	Pascal type	1.00	0.06
115	asparagus, (fresh/frozen), boiled	leafy veg	fresh, cuts & tips	1.00	0.06
116	cauliflower, (fresh/frozen), boiled	leafy veg	raw, flower buds	1.00	0.07
117	tomato, raw	garden fruit		1.00	0.06
118	tomato juice, canned	garden fruit		1.00	0.06
119	tomato sauce, canned	garden fruit	only spices, no sugar added	1.00	0.11
120	tomatoes, canned	garden fruit	solids & liquids	1.00	0.06
121	beans, snap green, (fresh/frozen),boiled	legume veg	fresh	1.00	0.08
122	beans, snap green, canned	legume veg	drained & cut	1.00	0.08
123	cucumber, raw, pared	garden fruit		1.00	0.05
124	squash, summer, (fresh/frozen), boiled	garden fruit		1.00	0.04
125	sweet pepper, green, raw	garden fruit		1.00	0.07
126	squash, winter (Hubbard/acorn), (raw/frozen), boiled	garden fruit	all varieties, baked	1.00	0.19
127	carrots, raw	root veg	pared, with crown & tip	1.00	0.12
128	onion, raw	root veg	mature, chopped	1.00	0.11
129	vegetables, mixed, canned	legume veg	peas	0.37	0.18
129	vegetables, mixed, canned	legume veg	green beans	0.23	0.18
129	vegetables, mixed, canned	corn		0.19	0.18
129	vegetables, mixed, canned	root veg	carrots	0.12	0.18
129	vegetables, mixed, canned	legume veg	lima beans	0.09	0.18
130	mushrooms, canned	mushroom	drained	1.00	0.10
131	beets, canned	root veg	drained	1.00	0.11
132	radish, raw	root veg		1.00	0.05
133	onion rings, breaded & fried, frozen, commercial,heated	root veg		0.66	0.72
133	onion rings, breaded & fried, frozen, commercial,heated	veg oil		0.23	1.00
133	onion rings, breaded & fried, frozen, commercial,heated	wheat		0.11	0.88
134	French fries, frozen, commercial, heated	potato	oven heated	0.92	0.18
134	French fries, frozen, commercial, heated	veg oil		0.08	1.00
135	mashed potatoes w/marg. & milk, prepared from instant	water		0.52	0.00
135	mashed potatoes w/marg. & milk, prepared from instant	potato	dried flakes	0.40	0.99
135	mashed potatoes w/marg. & milk, prepared from instant	dairy	milk	0.06	0.08
135	mashed potatoes w/marg. & milk, prepared from instant	veg oil		0.01	0.99
135	mashed potatoes w/marg. & milk, prepared from instant	dairy fat	milk	0.01	1.00
136	boiled potato without peel	potato	peeled before cooking	1.00	0.17
137	baked potato with peel	potato	peeled after baking	1.00	0.25
138	potato chips, commercial	potato		0.60	0.96
138	potato chips, commercial	veg oil		0.40	1.00
139	scalloped potatoes, homemade	potato		0.55	0.26
139	scalloped potatoes, homemade	dairy	milk	0.20	0.08
139	scalloped potatoes, homemade	veg oil		0.15	1.00
139	scalloped potatoes, homemade	wheat		0.07	0.88
139	scalloped potatoes, homemade	root veg	onion	0.02	0.11
139	scalloped potatoes, homemade	dairy fat	milk	0.01	1.00
140	sweet potato, baked in skin	potato	peeled after baking	1.00	0.36
141	sweet potato, candied, homemade	potato		0.55	0.26
141	sweet potato, candied, homemade	other	sugar	0.31	0.99
141	sweet potato, candied, homemade	veg oil		0.14	1.00
142	spaghetti with meat sauce, homemade	water		0.44	0.00
142	spaghetti with meat sauce, homemade	wheat	noodles	0.33	0.88
142	spaghetti with meat sauce, homemade	beef		0.07	0.26

Table A1-1

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM
142	spaghetti with meat sauce, homemade	garden fruit	tomato	0.06	0.10
142	spaghetti with meat sauce, homemade	other	sugar	0.03	0.99
142	spaghetti with meat sauce, homemade	egg	noodles	0.03	0.25
142	spaghetti with meat sauce, homemade	beef fat		0.02	1.00
142	spaghetti with meat sauce, homemade	root veg	onion	0.01	0.14
142	spaghetti with meat sauce, homemade	leafy veg	parsley	0.01	0.15
143	beef and vegetable stew, homemade	beef		0.45	0.33
143	beef and vegetable stew, homemade	potato		0.17	0.20
143	beef and vegetable stew, homemade	root veg	carrot	0.16	0.12
143	beef and vegetable stew, homemade	beef fat		0.14	1.00
143	beef and vegetable stew, homemade	other	seasoning	0.05	1.00
143	beef and vegetable stew, homemade	wheat		0.03	0.88
144	pizza, cheese, frozen, commercial, heated	other	sugar	0.40	0.99
144	pizza, cheese, frozen, commercial, heated	wheat		0.25	0.88
144	pizza, cheese, frozen, commercial, heated	veg oil		0.12	1.00
144	pizza, cheese, frozen, commercial, heated	dairy	cheese	0.10	0.08
144	pizza, cheese, frozen, commercial, heated	dairy fat	cheese	0.08	1.00
144	pizza, cheese, frozen, commercial, heated	garden fruit	tomato sauce	0.05	0.20
145	chili con carne, beef and beans, canned	beef		0.34	0.12
145	chili con carne, beef and beans, canned	legume veg	beans	0.33	0.15
145	chili con carne, beef and beans, canned	garden fruit	tomato sauce	0.16	0.10
145	chili con carne, beef and beans, canned	root veg	onions	0.12	0.15
145	chili con carne, beef and beans, canned	beef fat		0.05	1.00
146	macaroni and cheese, prepared from box mix	water		0.29	0.00
146	macaroni and cheese, prepared from box mix	wheat	noodles	0.29	0.88
146	macaroni and cheese, prepared from box mix	dairy	cheese	0.15	0.35
146	macaroni and cheese, prepared from box mix	dairy	milk	0.13	0.08
146	macaroni and cheese, prepared from box mix	dairy fat	cheese	0.08	1.00
146	macaroni and cheese, prepared from box mix	egg	noodles	0.05	0.25
146	macaroni and cheese, prepared from box mix	dairy fat	milk	0.01	1.00
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	wheat		0.34	0.65
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	beef		0.32	0.12
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	veg oil		0.20	1.00
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	beef fat		0.10	1.00
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	garden fruit	tomato	0.02	0.07
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	root veg	onion	0.01	0.10
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	leafy veg	lettuce	0.01	0.05
148	meatloaf, beef, homemade	beef		0.40	0.26
148	meatloaf, beef, homemade	garden fruit	tomato catsup	0.21	0.30
148	meatloaf, beef, homemade	wheat		0.19	0.88
148	meatloaf, beef, homemade	beef fat		0.13	1.00
148	meatloaf, beef, homemade	egg		0.05	0.26
148	meatloaf, beef, homemade	root veg	onion	0.02	0.11
149	spaghetti in tomato sauce, canned	wheat	noodles	0.77	0.18
149	spaghetti in tomato sauce, canned	egg	noodles	0.17	0.25
149	spaghetti in tomato sauce, canned	garden fruit	tomato sauce	0.06	0.30
150	chicken noodle casserole, homemade	wheat	noodles	0.39	0.29
150	chicken noodle casserole, homemade	veg oil		0.15	1.00
150	chicken noodle casserole, homemade	poultry		0.12	0.45
150	chicken noodle casserole, homemade	egg		0.11	0.25
150	chicken noodle casserole, homemade	dairy	milk	0.09	0.08
150	chicken noodle casserole, homemade	garden fruit		0.06	0.10
150	chicken noodle casserole, homemade	poultry fat		0.05	1.00
150	chicken noodle casserole, homemade	dairy fat	milk, cheese	0.02	1.00
150	chicken noodle casserole, homemade	dairy	cheese	0.01	0.84
151	lasagne, homemade	wheat	noodles	0.40	0.30

Table A1-1

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM
151	lasagne, homemade	dairy	cheese	0.24	0.31
151	lasagne, homemade	beef		0.14	0.30
151	lasagne, homemade	dairy fat		0.12	1.00
151	lasagne, homemade	beef fat		0.05	1.00
151	lasagne, homemade	garden fruit	tomato	0.03	0.06
151	lasagne, homemade	egg		0.02	0.26
152	potpie, frozen, commercial, chicken, oven heated	wheat		0.30	0.88
152	potpie, frozen, commercial, chicken, oven heated	poultry		0.26	0.17
152	potpie, frozen, commercial, chicken, oven heated	egg		0.14	0.24
152	potpie, frozen, commercial, chicken, oven heated	legume veg	pea	0.09	0.12
152	potpie, frozen, commercial, chicken, oven heated	potato		0.07	0.17
152	potpie, frozen, commercial, chicken, oven heated	poultry fat		0.06	1.00
152	potpie, frozen, commercial, chicken, oven heated	veg oil		0.05	1.00
152	potpie, frozen, commercial, chicken, oven heated	root veg	carrot	0.03	0.09
153	pork chow mein, homemade	water		0.58	0.00
153	pork chow mein, homemade	pork		0.23	0.24
153	pork chow mein, homemade	other	celery, water chestnuts, sprouts	0.10	0.04
153	pork chow mein, homemade	veg oil		0.04	1.00
153	pork chow mein, homemade	pork fat		0.03	1.00
153	pork chow mein, homemade	corn	cornstarch	0.01	0.89
153	pork chow mein, homemade	mushrooms		0.01	0.04
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	wheat		0.33	0.88
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	poultry		0.30	0.15
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	potato		0.09	0.13
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	veg oil		0.07	1.00
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	dairy	milk	0.07	0.08
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	legume veg	assume peas or beans	0.07	0.21
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	poultry fat		0.04	1.00
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	other	sugar	0.02	0.99
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	dairy fat	milk	0.01	1.00
155	chicken noodle soup, canned, reconstituted with water	water		0.89	0.00
155	chicken noodle soup, canned, reconstituted with water	wheat		0.04	0.88
155	chicken noodle soup, canned, reconstituted with water	poultry		0.03	0.14
155	chicken noodle soup, canned, reconstituted with water	egg		0.02	0.26
155	chicken noodle soup, canned, reconstituted with water	veg oil		0.01	1.00
155	chicken noodle soup, canned, reconstituted with water	corn	corn syrup	0.01	0.89
156	tomato soup, canned, reconstituted with whole milk	dairy	milk	0.39	0.08
156	tomato soup, canned, reconstituted with whole milk	corn	corn syrup	0.25	0.99
156	tomato soup, canned, reconstituted with whole milk	garden fruit	tomato	0.22	0.18
156	tomato soup, canned, reconstituted with whole milk	veg oil		0.11	1.00
156	tomato soup, canned, reconstituted with whole milk	dairy fat		0.03	1.00
157	vegetable beef soup, canned, reconstituted with water	water		0.90	0.00
157	vegetable beef soup, canned, reconstituted with water	wheat		0.03	0.88
157	vegetable beef soup, canned, reconstituted with water	corn	corn starch	0.02	0.89
157	vegetable beef soup, canned, reconstituted with water	beef		0.02	0.10
157	vegetable beef soup, canned, reconstituted with water	corn	corn syrup	0.01	0.99
157	vegetable beef soup, canned, reconstituted with water	potato		0.01	0.10
157	vegetable beef soup, canned, reconstituted with water	legume veg		0.01	0.12
158	beef bouillon, canned, reconstituted with water	water		0.91	0.00
158	beef bouillon, canned, reconstituted with water	beef		0.74	0.14
158	beef bouillon, canned, reconstituted with water	other	sugar	0.25	0.99
158	beef bouillon, canned, reconstituted with water	beef fat		0.11	1.00
159	gravy, brown, from mix	water		0.98	0.00
159	gravy, brown, from mix	other	sugar	0.01	0.99
159	gravy, brown, from mix	corn	corn starch	0.01	0.89
160	white sauce, medium, homemade	dairy	milk	0.79	0.08

Table A1-1

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM
160	white sauce, medium, homemade	dairy fat	butter, milk	0.13	1.00
160	white sauce, medium, homemade	wheat		0.08	0.88
161	pickles, dill, bottled	garden fruit	cucmber	1.00	0.07
162	margarine made w/partially hydrog. veg. oil, stick type	veg oil		1.00	0.84
163	salad dressing, italian, bottled	veg oil	regular	1.00	0.72
164	butter, stick type	dairy fat	regular	1.00	0.84
165	vegetable oil, corn, bottled	veg oil		1.00	1.00
166	mayonnaise, bottled	egg		0.60	0.08
166	mayonnaise, bottled	veg oil		0.40	1.00
167	cream, half and half, fluid	dairy	cream & milk	0.90	0.12
167	cream, half and half, fluid	dairy fat		0.10	1.00
168	cream substitute, powdered	other	vegetable fat & sweetener	1.00	0.10
169	sugar, white, granulated	other		1.00	0.99
170	syrup, pancake, bottled	other	sugar	0.51	0.99
170	syrup, pancake, bottled	water		0.27	0.00
170	syrup, pancake, bottled	corn	corn syrup	0.22	0.73
171	jelly, grape, bottled	other	sugar	0.75	0.99
171	jelly, grape, bottled	other	fruit	0.25	0.37
172	honey, bottled	other		1.00	0.83
173	catsup, bottled	garden fruit		0.45	0.07
173	catsup, bottled	other	vinegar	0.30	0.01
173	catsup, bottled	other	sugar	0.25	0.99
174	ice cream, chocolate	dairy		0.75	0.08
174	ice cream, chocolate	other	sugar	0.15	0.99
174	ice cream, chocolate	dairy fat		0.10	1.00
175	pudding, chocolate, instant, made with whole milk	other	sugar	0.81	0.99
175	pudding, chocolate, instant, made with whole milk	dairy		0.16	0.08
175	pudding, chocolate, instant, made with whole milk	dairy fat		0.03	1.00
176	ice cream sandwich	wheat		0.73	0.63
176	ice cream sandwich	other	sugar	0.15	0.99
176	ice cream sandwich	dairy		0.10	0.08
176	ice cream sandwich	dairy fat		0.02	1.00
177	ice milk, vanilla	dairy		0.80	0.20
177	ice milk, vanilla	other	sugar	0.15	0.99
177	ice milk, vanilla	dairy fat		0.05	1.00
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	other	sugar, cocoa	0.44	0.99
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	wheat		0.25	0.63
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	veg oil		0.17	1.00
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	dairy		0.06	0.08
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	dairy fat		0.04	1.00
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	egg		0.04	0.25
179	yellow cake prep. from mix w/white icing prep. from mix	other	sugar	0.44	0.99
179	yellow cake prep. from mix w/white icing prep. from mix	wheat		0.25	0.63
179	yellow cake prep. from mix w/white icing prep. from mix	veg oil		0.17	1.00
179	yellow cake prep. from mix w/white icing prep. from mix	dairy		0.06	0.08
179	yellow cake prep. from mix w/white icing prep. from mix	egg		0.04	0.25
179	yellow cake prep. from mix w/white icing prep. from mix	dairy fat		0.04	1.00
180	coffeecake, (ready-to-eat/frozen)	dairy		0.25	0.08
180	coffeecake, (ready-to-eat/frozen)	wheat		0.24	0.88
180	coffeecake, (ready-to-eat/frozen)	other	sugar, etc.	0.22	0.99
180	coffeecake, (ready-to-eat/frozen)	veg oil		0.20	1.00
180	coffeecake, (ready-to-eat/frozen)	egg		0.07	0.25
180	coffeecake, (ready-to-eat/frozen)	dairy fat		0.02	1.00
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	wheat		0.37	0.88
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	other	sugar	0.25	0.99
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	veg oil		0.20	1.00

Table A1-1

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	water		0.14	0.00
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	dairy	non-fat	0.03	0.08
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	egg	white	0.01	0.25
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	wheat		0.46	0.88
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	dairy		0.21	0.08
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	veg oil	margarine	0.20	1.00
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	other	sugar	0.07	0.99
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	egg		0.05	0.25
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	dairy fat		0.01	1.00
183	cookies, chocolate chip	wheat		0.48	0.97
183	cookies, chocolate chip	other	sugar	0.26	0.99
183	cookies, chocolate chip	veg oil		0.13	1.00
183	cookies, chocolate chip	other	chocolate chips	0.07	0.98
183	cookies, chocolate chip	egg		0.06	0.80
184	cookies, sandwich type, chocolate w/white cream filling	wheat		0.48	0.97
184	cookies, sandwich type, chocolate w/white cream filling	other	sugar	0.36	0.99
184	cookies, sandwich type, chocolate w/white cream filling	veg oil		0.10	1.00
184	cookies, sandwich type, chocolate w/white cream filling	egg		0.06	0.80
185	apple pie, frozen, heated	wheat		0.33	0.88
185	apple pie, frozen, heated	other	sugar	0.28	0.99
185	apple pie, frozen, heated	other	apples	0.21	0.14
185	apple pie, frozen, heated	veg oil		0.18	1.00
186	pumpkin pie, frozen, heated	garden fruit	pumpkin	0.40	0.26
186	pumpkin pie, frozen, heated	wheat		0.30	0.88
186	pumpkin pie, frozen, heated	dairy	evaporated milk	0.18	0.21
186	pumpkin pie, frozen, heated	egg		0.17	0.25
186	pumpkin pie, frozen, heated	veg oil		0.09	1.00
186	pumpkin pie, frozen, heated	dairy fat		0.02	1.00
187	candy, plain milk chocolate	other	sugar	0.52	0.99
187	candy, plain milk chocolate	veg oil		0.23	1.00
187	candy, plain milk chocolate	other	cocoa	0.22	0.99
187	candy, plain milk chocolate	other	cocoa fat	0.03	1.00
188	candy, carmels	other	sugar	0.70	0.99
188	candy, carmels	dairy		0.16	0.08
188	candy, carmels	other	cocoa fat	0.07	1.00
188	candy, carmels	other	cocoa, based on chocolate	0.04	0.99
188	candy, carmels	dairy fat		0.03	1.00
189	chocolate powder,sweetened,to mix w/ hot or cold milk	other	sugar	0.52	0.99
189	chocolate powder,sweetened,to mix w/ hot or cold milk	other	cocoa	0.37	0.99
189	chocolate powder,sweetened,to mix w/ hot or cold milk	other	cocoa fat	0.11	1.00
190	gelatin dessert, prepared, strawberry	water		0.97	0.00
190	gelatin dessert, prepared, strawberry	other	sugar and gelatin	0.03	0.98
191	carbonated soda, sweetened, cola type, canned	water		0.98	0.00
191	carbonated soda, sweetened, cola type, canned	other	sugars, syrups and flavorings	0.02	0.91
192	carbonated soda, sweetened, lemon-lime, canned	water		0.98	0.00
192	carbonated soda, sweetened, lemon-lime, canned	other	sugars, syrups and flavorings	0.02	0.91
193	soft drink from powder, cherry flavor, presweetened	water		0.98	0.00
193	soft drink from powder, cherry flavor, presweetened	other	sugar and mix	0.02	0.99
194	soda, low calorie, cola, sweetened w/saccharine, canned	water		0.98	0.00
194	soda, low calorie, cola, sweetened w/saccharine, canned	other	flavor, saccarine	0.02	0.99
195	coffee beverage, from instant	other	water	0.98	0.00
195	coffee beverage, from instant	other	coffee beans	0.02	0.01
196	coffee beverage, from instant, decaffeinated	other	water	0.98	0.00
196	coffee beverage, from instant, decaffeinated	other	coffee beans	0.02	0.01
197	tea beverage, hot, made with tea bag	other	water	0.98	0.00
197	tea beverage, hot, made with tea bag	other	tea	0.02	0.98

Table A1-1

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM
198	beer, canned	water		0.92	0.00
198	beer, canned	other grain	hop&barley-derived alcohol&solids	0.08	1.00
199	wine, table, 12.2% alcohol	water		0.86	0.00
199	wine, table, 12.2% alcohol	other	grape-derived alcohol & solids	0.14	1.00
200	whisky, 80-proof	water		0.67	0.00
200	whisky, 80-proof	other	alcohol & solids	0.33	1.00
201	water	water		1.00	0.00
202	milk-based infant formula w/iron,canned,ready-to serve	other	sugars, syrups	0.32	0.99
202	milk-based infant formula w/iron,canned,ready-to serve	dairy		0.31	0.08
202	milk-based infant formula w/iron,canned,ready-to serve	dairy fat		0.19	1.00
202	milk-based infant formula w/iron,canned,ready-to serve	veg oil		0.18	1.00
203	milk-based infant formula w/o iron,canned,ready-to-serv	other	sugar, syrups	0.32	0.99
203	milk-based infant formula w/o iron,canned,ready-to-serv	dairy		0.31	0.08
203	milk-based infant formula w/o iron,canned,ready-to-serv	dairy fat		0.19	1.00
203	milk-based infant formula w/o iron,canned,ready-to-serv	veg oil		0.18	1.00
204	infant mixed cereal, prepared from dry with whole milk	dairy		0.78	0.08
204	infant mixed cereal, prepared from dry with whole milk	wheat		0.18	0.92
204	infant mixed cereal, prepared from dry with whole milk	dairy fat		0.04	1.00
205	beef, (st./jr.)	beef	strained	0.96	0.16
205	beef, (st./jr.)	beef fat		0.04	1.00
206	pork, (st./jr.)	pork	strained	0.94	0.18
206	pork, (st./jr.)	pork fat		0.06	1.00
207	chicken/turkey, (st./jr.)	poultry	strained, chicken	0.92	0.16
207	chicken/turkey, (st./jr.)	poultry fat		0.08	1.00
208	high meat (chicken/turkey) and vegetables, (st./jr.)	poultry		0.40	0.16
208	high meat (chicken/turkey) and vegetables, (st./jr.)	root veg	carrot	0.28	0.14
208	high meat (chicken/turkey) and vegetables, (st./jr.)	legume veg	peas, beans	0.28	0.09
208	high meat (chicken/turkey) and vegetables, (st./jr.)	poultry fat		0.04	1.00
209	high meat beef and vegetables, (st./jr.)	beef	strained	0.39	0.13
209	high meat beef and vegetables, (st./jr.)	root veg	carrot	0.29	0.14
209	high meat beef and vegetables, (st./jr.)	legume veg	peas, beans	0.28	0.09
209	high meat beef and vegetables, (st./jr.)	beef fat		0.04	1.00
210	high meat ham and vegetables, (st./jr.)	pork	strained	0.41	0.14
210	high meat ham and vegetables, (st./jr.)	root veg	carrot	0.28	0.14
210	high meat ham and vegetables, (st./jr.)	legume veg		0.27	0.09
210	high meat ham and vegetables, (st./jr.)	pork fat		0.04	1.00
211	vegetables with beef, (st./jr.)	legume veg	peas, beans	0.40	0.09
211	vegetables with beef, (st./jr.)	root veg	carrot	0.40	0.14
211	vegetables with beef, (st./jr.)	beef	strained	0.18	0.06
211	vegetables with beef, (st./jr.)	beef fat		0.02	1.00
212	vegetables with (trukey/chicken), (st./jr.)	root veg	carrot	0.40	0.14
212	vegetables with (trukey/chicken), (st./jr.)	legume veg	peas, beans	0.40	0.09
212	vegetables with (trukey/chicken), (st./jr.)	poultry	turkey, strained	0.18	0.04
212	vegetables with (trukey/chicken), (st./jr.)	poultry fat		0.02	1.00
213	vegetables with (bacon/ham), (st./jr.)	root veg	carrot	0.37	0.14
213	vegetables with (bacon/ham), (st./jr.)	legume veg	peas, beans	0.37	0.09
213	vegetables with (bacon/ham), (st./jr.)	pork		0.24	0.10
213	vegetables with (bacon/ham), (st./jr.)	pork fat	bacon, strained	0.02	1.00
214	chicken and noodles, (st./jr.)	water		0.60	0.00
214	chicken and noodles, (st./jr.)	wheat		0.30	0.30
214	chicken and noodles, (st./jr.)	poultry	strained	0.07	0.19
214	chicken and noodles, (st./jr.)	egg		0.02	0.25
214	chicken and noodles, (st./jr.)	poultry fat		0.01	1.00
215	tomatoes, beef and macaroni, (st./jr.)	water		0.50	0.00
215	tomatoes, beef and macaroni, (st./jr.)	garden fruit	tomato	0.27	0.10
215	tomatoes, beef and macaroni, (st./jr.)	wheat		0.11	0.88

Table A1-1

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM
215	tomatoes, beef and macaroni, (st./jr.)	beef	strained	0.08	0.15
215	tomatoes, beef and macaroni, (st./jr.)	egg		0.02	0.25
215	tomatoes, beef and macaroni, (st./jr.)	beef fat		0.02	1.00
216	turkey and rice, (st./jr.)	rice		0.80	0.17
216	turkey and rice, (st./jr.)	poultry	strained	0.18	0.19
216	turkey and rice, (st./jr.)	poultry fat		0.02	1.00
217	oatmeal with applesauce and bananas, (st./jr.)	water		0.58	0.00
217	oatmeal with applesauce and bananas, (st./jr.)	other	fruits; apples & bananas	0.29	0.20
217	oatmeal with applesauce and bananas, (st./jr.)	oats		0.13	0.88
218	carrots, (st./jr.)	root veg	strained	1.00	0.08
219	green beans, (st./jr.)	legume veg	strained	1.00	0.08
220	mixed vegetables/garden vegetables, (st./jr.)	leafy veg	strained	1.00	0.10
221	sweet potatoes/yellow squash, (st./jr.)	potato	sweet potato strained	1.00	0.15
222	corn, creamed, (st./jr.)	wheat	strained	1.00	0.16
223	peas, (st./jr.)	legume veg	strained	1.00	0.13
224	spinach, creamed, (st./jr.)	leafy veg	strained	1.00	0.10
225	applesauce/applesauce with other fruit, (st./jr.)	other	strained	1.00	0.11
226	peaches, (st./jr.)	other	strained	1.00	0.20
227	pear/pear and pineapple, (st./jr.)	other	strained	1.00	0.12
228	bananas and pineapple with tapioca, (st./jr.)	water		0.47	0.00
228	bananas and pineapple with tapioca, (st./jr.)	other	strained	0.32	0.10
228	bananas and pineapple with tapioca, (st./jr.)	wheat		0.21	0.88
229	prunes/plums with tapioca, (st./jr.)	water		0.47	0.00
229	prunes/plums with tapioca, (st./jr.)	other	strained prunes	0.32	0.10
229	prunes/plums with tapioca, (st./jr.)	wheat		0.21	0.88
230	apple/apple chery/apple grape juice, strained	other	strained apoles	1.00	0.12
231	orange/orange pineapple juice, strained	other	strained oranges	1.00	0.12
232	pudding/custard, any flavor, (st./jr.)	water		0.74	0.00
232	pudding/custard, any flavor, (st./jr.)	other	sugar	0.16	0.99
232	pudding/custard, any flavor, (st./jr.)	rice	rice starch	0.03	0.89
232	pudding/custard, any flavor, (st./jr.)	corn	corn starch	0.03	0.89
232	pudding/custard, any flavor, (st./jr.)	dairy	non-fat dry milk	0.02	0.99
232	pudding/custard, any flavor, (st./jr.)	dairy fat	heavy cream	0.01	1.00
232	pudding/custard, any flavor, (st./jr.)	egg	egg yolk	0.01	0.45
233	fruit dessert with tapioca, any fruit, (st./jr.)	water		0.47	0.00
233	fruit dessert with tapioca, any fruit, (st./jr.)	other	fruit, aggregate	0.32	0.10
233	fruit dessert with tapioca, any fruit, (st./jr.)	wheat		0.21	0.88
234	dutch apple/apple betty, (st./jr.)	water		0.47	0.00
234	dutch apple/apple betty, (st./jr.)	other	sugar	0.29	0.99
234	dutch apple/apple betty, (st./jr.)	other	apple	0.20	0.12
234	dutch apple/apple betty, (st./jr.)	wheat		0.04	0.88

TABLE A1-2*

Reanalysis of FDA Revised Total Diet Food List: Category Totals as Both Wet Weight and Dry Weight (and the Ratio of Wet:Dry Weights) for Each Food Group, for All Age/Sex Groups

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*Refer to the text of Section 4.1.4. for discussion of the purposes and methods for this reanalysis.

Table A1-2

CATEGORY TOTALS	6-11 MO. WET WT.	6-11 MO. DRY WT.	6-11 MO. D/W RATIO	2 YR. WET WT.	2 YR. DRY WT.	2 YR. D/W RATIO	14-16 F WET WT.	14-16 F DRY WT.	14-16 F D/W RATIO
wheat	42.6161	27.6020	0.6477	57.1387	42.2344	0.7392	86.8392	61.5025	0.7082
corn	8.7010	3.9986	0.4596	27.6014	15.3541	0.5563	34.2138	18.5795	0.5430
rice	8.2406	2.2249	0.2700	14.1732	4.5845	0.3235	17.4356	5.1368	0.2946
oats	14.6805	3.7298	0.2541	13.3744	2.6502	0.1982	3.9988	1.0994	0.2749
other grain	0.0118	0.0106	0.8996	0.0870	0.0771	0.8863	0.1154	0.1022	0.8859
potato	18.3803	5.6673	0.3083	30.7320	10.0335	0.3265	47.0903	15.9724	0.3392
leafy veg	8.6480	0.8380	0.0969	7.2183	0.4854	0.0672	21.1097	1.1341	0.0537
legume veg	32.3465	3.8094	0.1178	20.1335	4.5571	0.2263	28.0241	6.3902	0.2280
root veg	24.8507	3.0400	0.1223	5.1002	0.6678	0.1309	8.7326	1.3125	0.1503
garden fruit	4.9824	0.6650	0.1335	15.9343	1.6690	0.1047	28.8519	3.0740	0.1065
peanuts	0.3422	0.3363	0.9828	2.2476	2.2082	0.9825	1.8143	1.7821	0.9823
mushroom	0.0032	0.0001	0.0400	0.1321	0.0127	0.0963	0.5637	0.0551	0.0978
veg oil	27.7791	27.6209	0.9943	18.3807	17.6867	0.9622	31.5384	30.2176	0.9581
beef	19.8554	3.9890	0.2009	31.3435	9.6621	0.3083	52.4039	16.6613	0.3179
beef fat	2.4448	2.4448	1.0000	6.4794	6.4794	1.0000	12.5395	12.5395	1.0000
beef liver	0.4503	0.1666	0.3700	0.6488	0.2401	0.3700	0.7476	0.2766	0.3700
beef liver fat	0.0455	0.0455	1.0000	0.0656	0.0656	1.0000	0.0756	0.0756	1.0000
lamb	0.4097	0.1393	0.3400	0.2258	0.0768	0.3400	0.1818	0.0618	0.3400
lamb fat	0.1443	0.1443	1.0000	0.0795	0.0795	1.0000	0.0640	0.0640	1.0000
pork	6.8858	1.3382	0.1943	12.6143	4.2907	0.3401	20.1434	7.4094	0.3678
pork fat	2.0059	2.0059	1.0000	8.1900	8.1900	1.0000	10.2186	10.2186	1.0000
poultry	12.1365	2.2693	0.1870	11.9110	3.7573	0.3155	18.8920	6.3271	0.3349
poultry fat	1.0957	1.0957	1.0000	0.8319	0.8319	1.0000	1.2237	1.2237	1.0000
fish	1.2922	0.3387	0.2621	4.4368	1.2005	0.2706	9.4185	2.5395	0.2696
dairy	485.8973	40.6970	0.0838	374.3778	32.9356	0.0880	380.8075	34.0111	0.0893
dairy fat	39.0454	38.9867	0.9985	16.6786	16.4844	0.9884	18.9735	18.7030	0.9857
egg	12.4660	3.2709	0.2624	25.3146	6.9135	0.2731	22.8215	6.0974	0.2672
other	245.2675	78.8062	0.3213	264.1923	67.7638	0.2565	318.1710	85.1162	0.2675
water*	242.6946	0.0000	0.0000	535.4675	0.0000	0.0000	779.6691	0.0000	0.0000

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*Note: "water"includes drinking water plus much of the water used in food preparation, including some commercially prepared foods. It would not be appropriate to use this category to represent drinking water consumption. See Table A1-1.

Table A1-2

CATEGORY TOTALS	14-16 M WET WT.	14-16 M DRY WT.	14-16 M D/W RATIO	25-30 F WET WT.	25-30 F DRY WT.	25-30 F D/W RATIO	25-30 M WET WT.	25-30 M DRY WT.	25-30 M D/W RATIO
wheat	127.8282	97.2110	0.7605	70.5907	52.8166	0.7482	103.6207	78.5058	0.7576
corn	48.4169	27.8431	0.5751	25.7594	13.8710	0.5385	38.1493	21.7827	0.5710
rice	21.0632	6.6381	0.3152	16.4460	4.7765	0.2904	23.6111	6.7825	0.2873
oats	8.0278	2.6740	0.3331	4.9716	1.0900	0.2192	3.4860	1.5519	0.4452
other grain	1.3764	1.3660	0.9924	2.8809	2.8673	0.9953	24.0496	24.0360	0.9994
potato	62.1648	22.8305	0.3673	41.8649	13.2108	0.3156	68.2186	21.3447	0.3129
leafy veg	22.2507	1.2970	0.0583	39.3291	2.1703	0.0552	38.9558	2.1527	0.0553
legume veg	45.9605	10.5176	0.2288	33.2367	7.8752	0.2369	50.2608	11.7527	0.2338
root veg	11.2979	2.1398	0.1894	10.8595	1.5157	0.1396	13.7585	2.0296	0.1475
garden fruit	37.0112	3.8632	0.1044	44.2448	4.1004	0.0927	53.8377	5.4053	0.1004
peanuts	4.1163	4.0428	0.9822	1.5687	1.5396	0.9815	3.3780	3.3153	0.9814
mushroom	0.3392	0.0320	0.0945	1.3972	0.1374	0.0984	1.3821	0.1355	0.0980
veg oil	46.2229	44.5719	0.9643	31.8582	29.7018	0.9323	47.0562	44.7022	0.9500
beef	82.5122	26.5872	0.3222	57.5594	17.3708	0.3018	100.8595	29.1939	0.2895
beef fat	19.8966	19.8966	1.0000	13.8234	13.8234	1.0000	26.9786	26.9786	1.0000
beef liver	1.1793	0.4363	0.3700	3.3268	1.2309	0.3700	2.4902	0.9214	0.3700
beef liver fat	0.1193	0.1193	1.0000	0.3364	0.3364	1.0000	0.2518	0.2518	1.0000
lamb	0.1292	0.0439	0.3400	0.9755	0.3317	0.3400	0.7647	0.2600	0.3400
lamb fat	0.0455	0.0455	1.0000	0.3435	0.3435	1.0000	0.2693	0.2693	1.0000
pork	29.5501	10.3101	0.3489	19.4106	7.0893	0.3652	38.1256	13.4471	0.3527
pork fat	15.2742	15.2742	1.0000	9.7095	9.7095	1.0000	19.2524	19.2524	1.0000
poultry	22.7704	7.7314	0.3395	18.9332	6.1537	0.3250	26.9727	9.1333	0.3386
poultry fat	1.5970	1.5970	1.0000	1.2416	1.2416	1.0000	1.8352	1.8352	1.0000
fish	10.2308	2.6764	0.2616	13.2610	3.5013	0.2640	18.0740	4.6697	0.2584
dairy	602.8343	53.0223	0.0880	227.7170	22.5046	0.0988	328.6258	32.5447	0.0990
dairy fat	30.5399	30.1483	0.9872	15.5539	15.1627	0.9748	23.3098	22.7856	0.9775
egg	33.1420	8.9355	0.2696	25.6873	6.6567	0.2591	38.9586	10.0347	0.2576
other	400.4057	127.2669	0.3178	684.4461	80.8883	0.1182	770.1192	105.5348	0.1370
water*	993.3826	0.0000	0.0000	760.7679	0.0000	0.0000	1211.2006	0.0000	0.0000

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*Note: "water" includes drinking water plus much of the water used in food preparation, including some commercially prepared foods. It would not be appropriate to use this category to represent drinking water consumption. See Table A1-1.

Table A1-2

CATEGORY TOTALS	60-65 F WET WT.	60-65 F DRY WT.	60-65 F D/W RATIO	60-65 M WET WT.	60-65 M DRY WT.	60-65 M D/W RATIO
wheat	59.7653	45.8331	0.7669	83.7464	64.4170	0.7692
corn	24.6186	12.3873	0.5032	34.4089	17.2590	0.5016
rice	13.2143	4.0244	0.3045	14.9052	4.3960	0.2949
oats	10.6708	1.8611	0.1744	13.9961	2.1391	0.1528
other grain	0.8650	0.8504	0.9831	7.9789	7.9668	0.9985
potato	40.9355	12.0376	0.2941	58.6095	17.5425	0.2993
leafy veg	45.4374	2.7815	0.0612	43.2402	2.5232	0.0584
legume veg	39.3826	8.1826	0.2078	50.6034	10.8195	0.2138
root veg	12.2724	1.5110	0.1231	14.5643	1.7705	0.1216
garden fruit	53.3809	4.5935	0.0861	56.5952	5.1207	0.0905
peanuts	1.3649	1.3398	0.9817	2.5269	2.4798	0.9814
mushroom	0.5252	0.0508	0.0967	0.7220	0.0705	0.0976
veg oil	25.3996	23.7050	0.9333	33.9531	31.9650	0.9414
beef	44.7308	14.1238	0.3158	71.4865	22.5623	0.3156
beef fat	10.7518	10.7518	1.0000	17.3979	17.3979	1.0000
beef liver	2.6050	0.9639	0.3700	3.8991	1.4427	0.3700
beef liver fat	0.2634	0.2634	1.0000	0.3943	0.3943	1.0000
lamb	0.6205	0.2110	0.3400	0.6276	0.2134	0.3400
lamb fat	0.2185	0.2185	1.0000	0.2210	0.2210	1.0000
pork	20.4924	7.5549	0.3687	32.2836	12.3284	0.3819
pork fat	9.9596	9.9596	1.0000	16.1116	16.1116	1.0000
poultry	19.5823	6.2793	0.3207	22.9363	7.4611	0.3253
poultry fat	1.2157	1.2157	1.0000	1.3982	1.3982	1.0000
fish	13.9818	3.6293	0.2596	16.1610	4.1075	0.2542
dairy	197.4623	19.3580	0.0980	264.7795	25.4705	0.0962
dairy fat	12.6655	12.2980	0.9710	17.2528	16.7264	0.9695
egg	28.2007	7.1952	0.2551	44.6082	11.4666	0.2571
other	858.2119	78.6520	0.0916	890.3108	94.0083	0.1056
water*	718.0376	0.0000	0.0000	876.8671	0.0000	0.0000

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*Note: "water"includes drinking water plus much of the water used in food preparation, including some commercially prepared foods. It would not be appropriate to use this category to represent drinking water consumption. See Table A1-1.

TABLE A1-3*

Reanalysis of FDA Revised Total Diet Food List:
Consumption Data (g/day) as Both Wet Weight and Dry Weight
for Each Component of Each Food Item, for All Age/Sex Groups.
Sorted by Food Category to Permit Summing of Categories.

Part A - Crops

Part B - Meat, Dairy and Other (Including Fruit)

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*Refer to the text of Section 4.1.4. for discussion of the purposes and methods for this reanalysis.

Table A1-3: Part A - Crops

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
023	veal cutlet, breaded, pan cooked with added fat	wheat		0.20	0.88	0.000	0.0000	0.0000	0.2120	0.0424	0.0373	0.4520	0.0904	0.0796	0.3870	0.0774	0.0681
024	chicken,drumstk/breast,breaded,fried w/add.fat,homemade	wheat		0.04	0.88	1.084	0.0434	0.0382	5.8820	0.2353	0.2070	9.4950	0.3798	0.3342	12.2340	0.4894	0.4306
033	shrimp(fresh/frozen),breaded&fried w/add. fat,homemade	wheat		0.10	0.88	0.000	0.0000	0.0000	0.1240	0.0124	0.0109	0.7600	0.0760	0.0669	1.1970	0.1197	0.1053
034	fish sticks, commercial, frozen, oven cooked	wheat		0.26	0.88	0.259	0.0673	0.0593	1.1560	0.3006	0.2645	1.7070	0.4438	0.3906	1.7160	0.4462	0.3926
052	farina, enriched, cooked	wheat	quick-cooking	1.00	0.11	6.070	6.0700	0.6677	3.5140	3.5140	0.3865	2.3800	2.3800	0.2618	3.7460	3.7460	0.4121
058	whitebread, enriched	wheat		0.35	0.88	6.303	2.2061	1.9413	26.8370	9.3929	8.2658	38.7510	13.5629	11.9353	55.6780	19.4873	17.1486
059	rolls, white, soft, enriched	wheat		0.72	0.88	0.770	0.5544	0.4879	4.1040	2.9549	2.6003	13.2400	9.5328	8.3889	21.4950	15.4764	13.6192
060	cornbread, southern style, homemade	wheat		0.14	0.88	0.877	0.1228	0.1080	3.2590	0.4563	0.4015	4.4320	0.6205	0.5460	6.8760	0.9626	0.8471
061	biscuits,baking powder,enriched,refrigerated type,baked	wheat		0.40	0.88	0.620	0.2480	0.2182	2.5820	1.0328	0.9089	3.6680	1.4672	1.2911	4.8560	1.9424	1.7093
062	whole wheat bread	wheat		0.36	0.88	0.653	0.2351	0.2069	2.7060	0.9742	0.8573	2.1560	0.7762	0.6830	3.3770	1.2157	1.0698
064	rye bread	wheat	2/3 wheat flour	0.24	0.88	0.082	0.0197	0.0173	0.6870	0.1649	0.1451	0.9140	0.2194	0.1930	0.7240	0.1738	0.1529
065	muffins (blueberry/plain)	wheat		0.47	0.88	0.039	0.0183	0.0161	0.6870	0.3229	0.2841	0.9140	0.4296	0.3780	0.7240	0.3403	0.2994
066	saltine crackers	wheat	enriched flour	0.90	0.88	2.874	2.5866	2.2762	3.3540	3.0186	2.6564	2.5210	2.2689	1.9966	3.0220	2.7198	2.3934
068	pancakes made from mix w/addition of egg, milk and oil	wheat		0.19	0.90	1.075	0.2043	0.1838	5.8330	1.1083	0.9974	5.7260	1.0879	0.9791	8.0120	1.5223	1.3701
069	noodles, egg, enriched, cooked	wheat		0.34	0.88	0.791	0.2689	0.2367	1.4090	0.4791	0.4216	1.7470	0.5940	0.5227	3.4270	1.1652	1.0254
070	macaroni, enriched, cooked	wheat	tender stage	1.00	0.27	1.232	1.2320	0.3326	3.2580	3.2580	0.8797	5.0270	5.0270	1.3573	8.4420	8.4420	2.2793
073	Shredded Wheat cereal	wheat		1.00	0.93	0.099	0.0990	0.0921	1.6420	1.6420	1.5271	1.3000	1.3000	1.2090	3.1260	3.1260	2.9072
074	Raisin Bran cereal	wheat	assume no sugar on raisins	0.57	0.97	0.047	0.0268	0.0260	1.1580	0.6601	0.6403	1.0600	0.6042	0.5861	2.9710	1.6935	1.6427
133	onion rings, breaded & fried, frozen, commercial,heated	wheat		0.11	0.88	0.050	0.0055	0.0048	0.0970	0.0107	0.0094	0.6870	0.0756	0.0665	1.8700	0.2057	0.1810
139	scalloped potatoes, homemade	wheat		0.07	0.88	1.023	0.0716	0.0630	2.0490	0.1434	0.1262	4.1450	0.2902	0.2553	5.8710	0.4110	0.3617
142	spaghetti with meat sauce, homemade	wheat	noodles	0.33	0.88	4.786	1.5794	1.3899	16.4100	5.4153	4.7655	17.4770	5.7674	5.0753	33.5700	11.0781	9.7487
143	beef and vegetable stew, homemade	wheat		0.03	0.88	2.838	0.0851	0.0749	5.7980	0.1739	0.1531	8.8880	0.2666	0.2346	10.8960	0.3269	0.2877
144	pizza, cheese, frozen, commercial, heated	wheat		0.25	0.88	0.484	0.1210	0.1065	3.1980	0.7995	0.7036	12.4450	3.1113	2.7379	39.9780	9.9945	8.7952
146	macaroni and cheese, prepared from box mix	wheat	noodles	0.29	0.88	3.545	1.0281	0.9047	7.4810	2.1695	1.9092	8.4490	2.4502	2.1562	12.0250	3.4873	3.0688
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	wheat		0.34	0.65	0.559	0.1901	0.1235	4.5740	1.5552	1.0109	13.6950	4.6563	3.0266	18.7500	6.3750	4.1438
148	meatloaf, beef, homemade	wheat		0.19	0.88	1.193	0.2267	0.1995	3.9830	0.7568	0.6660	6.4960	1.2342	1.0861	10.3690	1.9701	1.7337
149	spaghetti in tomato sauce, canned	wheat	noodles	0.77	0.18	2.259	1.7394	0.3131	4.6890	3.6105	0.6499	13.2220	10.1809	1.8326	5.3900	4.1503	0.7471
150	chicken noodle casserole, homemade	wheat	noodles	0.39	0.29	0.288	0.1123	0.0326	1.2130	0.4731	0.1372	1.7410	0.6790	0.1969	4.1590	1.6220	0.4704
151	lasagne, homemade	wheat	noodles	0.40	0.30	0.261	0.1044	0.0313	1.1370	0.4548	0.1364	2.5540	1.0216	0.3065	4.4070	1.7628	0.5288
152	potpie, frozen, commercial, chicken, oven heated	wheat		0.30	0.88	0.142	0.0426	0.0375	1.7610	0.5283	0.4649	1.4120	0.4236	0.3728	2.1170	0.6351	0.5589
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	wheat		0.33	0.88	0.065	0.0215	0.0189	1.6920	0.5584	0.4914	1.3290	0.4386	0.3859	0.8830	0.2914	0.2564
155	chicken noodle soup, canned, reconstituted with water	wheat		0.04	0.88	6.835	0.2734	0.2406	17.8080	0.7123	0.6268	12.6120	0.5045	0.4439	7.0820	0.2833	0.2493
157	vegetable beef soup, canned, reconstituted with water	wheat		0.03	0.88	5.792	0.1738	0.1529	16.1960	0.4859	0.4276	12.1130	0.3634	0.3198	13.2320	0.3970	0.3493
160	white sauce, medium, homemade	wheat		0.08	0.88	0.346	0.0277	0.0244	0.4670	0.0374	0.0329	0.5250	0.0420	0.0370	1.4300	0.1144	0.1007
176	ice cream sandwich	wheat		0.73	0.63	0.054	0.0394	0.0248	1.1640	0.8497	0.5353	1.9210	1.4023	0.8835	2.5240	1.8425	1.1608
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	wheat		0.25	0.63	0.170	0.0425	0.0268	2.3260	0.5815	0.3663	6.7310	1.6828	1.0601	8.5340	2.1335	1.3441
179	yellow cake prep. from mix w/white icing prep. from mix	wheat		0.25	0.63	0.634	0.1585	0.0999	3.1700	0.7925	0.4993	8.4330	2.1083	1.3282	12.1270	3.0318	1.9100
180	coffeecake, (ready-to-eat/frozen)	wheat		0.24	0.88	0.052	0.0125	0.0110	0.2910	0.0698	0.0615	1.2450	0.2988	0.2629	0.9190	0.2206	0.1941
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	wheat		0.37	0.88	0.516	0.1909	0.1680	2.3650	0.8751	0.7700	4.0180	1.4867	1.3083	6.6590	2.4638	2.1682
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	wheat		0.46	0.88	0.119	0.0547	0.0482	0.5470	0.2516	0.2214	2.0850	0.9591	0.8440	5.1720	2.3791	2.0936
183	cookies, chocolate chip	wheat		0.48	0.97	2.604	1.2499	1.2124	7.6350	3.6648	3.5549	5.8690	2.8171	2.7326	8.0760	3.8765	3.7602
184	cookies, sandwich type, chocolate w/white cream filling	wheat		0.48	0.97	0.844	0.4051	0.3930	3.1210	1.4981	1.4531	1.7950	0.8616	0.8358	3.9590	1.9003	1.8433
185	apple pie, frozen, heated	wheat		0.33	0.88	0.224	0.0739	0.0650	1.6930	0.5587	0.4916	5.9050	1.9487	1.7148	8.3570	2.7578	2.4269
186	pumpkin pie, frozen, heated	wheat		0.30	0.88	0.440	0.1320	0.1162	1.0020	0.3006	0.2645	3.0270	0.9081	0.7991	3.2390	0.9717	0.8551
204	infant mixed cereal, prepared from dry with whole milk	wheat		0.18	0.92	51.842	9.3316	8.5850	0.1470	0.0265	0.0243	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
214	chicken and noodles, (st./jr.)	wheat		0.30	0.30	9.458	2.8374	0.8512	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
215	tomatoes, beef and macaroni, (st./jr.)	wheat		0.11	0.88	3.958	0.4354	0.3831	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
222	corn, creamed, (st./jr.)	wheat	strained	1.00	0.16	2.659	2.6590	0.4254	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
228	bananas and pineapple with tapioca, (st./jr.)	wheat		0.21	0.88	14.303	3.0036	2.6432	0.2570	0.0540	0.0475	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table A1-3: Part A - Crops

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DW	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
023	veal cutlet, breaded, pan cooked with added fat	wheat		0.20	0.88	1.3450	0.2690	0.2367	0.8390	0.1678	0.1477	0.9510	0.1902	0.1674	1.3510	0.2702	0.2378
024	chicken,drumstk/breast,breaded,fried w/add.fat,homemade	wheat		0.04	0.88	8.9940	0.3598	0.3166	12.4750	0.4990	0.4391	7.3440	0.2938	0.2585	9.2560	0.3702	0.3258
033	shrimp(fresh/frozen),breaded&fried w/add. fat,homemade	wheat		0.10	0.88	2.6550	0.2655	0.2336	3.4720	0.3472	0.3055	1.9740	0.1974	0.1737	1.8440	0.1844	0.1623
034	fish sticks, commercial, frozen, oven cooked	wheat		0.26	0.88	1.7420	0.4529	0.3986	2.1410	0.5567	0.4899	1.0890	0.2831	0.2492	1.0530	0.2738	0.2409
052	farina, enriched, cooked	wheat	quick-cooking	1.00	0.11	1.9210	1.9210	0.2113	2.5300	2.5300	0.2783	3.6600	3.6600	0.4026	4.9810	4.9810	0.5479
058	whitebread, enriched	wheat		0.35	0.88	34.4240	12.0484	10.6026	36.7200	12.8520	11.3098	34.9880	12.2458	10.7763	50.8730	17.8055	15.6689
059	rolls, white, soft, enriched	wheat		0.72	0.88	10.0550	7.2396	6.3708	20.2870	14.6066	12.8538	6.0290	4.3409	3.8200	9.0500	6.5160	5.7341
060	cornbread, southern style, homemade	wheat		0.14	0.88	3.8690	0.5417	0.4767	8.8500	1.2390	1.0903	8.3130	1.1638	1.0242	11.9270	1.6698	1.4694
061	biscuits,baking powder,enriched,refrigerated type,baked	wheat		0.40	0.88	3.0630	1.2252	1.0782	5.0310	2.0124	1.7709	4.0800	1.6320	1.4362	7.8060	3.1224	2.7477
062	whole wheat bread	wheat		0.36	0.88	4.1780	1.5041	1.3236	7.7820	2.8015	2.4653	5.4900	1.9764	1.7392	6.5870	2.3713	2.0868
064	rye bread	wheat	2/3 wheat flour	0.24	0.88	0.9470	0.2273	0.2000	0.9450	0.2268	0.1996	1.0140	0.2434	0.2142	0.8380	0.2011	0.1770
065	muffins (blueberry/plain)	wheat		0.47	0.88	0.9470	0.4451	0.3917	0.9450	0.4441	0.3909	1.0140	0.4766	0.4194	0.8380	0.3939	0.3466
066	saltine crackers	wheat	enriched flour	0.90	0.88	3.4820	3.1338	2.7577	3.9120	3.5208	3.0983	3.5590	3.2031	2.8187	4.0590	3.6531	3.2147
068	pancakes made from mix w/addition of egg, milk and oil	wheat		0.19	0.90	4.4820	0.8516	0.7664	6.9760	1.3254	1.1929	3.6180	0.6874	0.6187	6.2960	1.1962	1.0766
069	noodles, egg, enriched, cooked	wheat		0.34	0.88	1.8590	0.6321	0.5562	2.4990	0.8497	0.7477	1.2100	0.4114	0.3620	2.3260	0.7908	0.6959
070	macaroni, enriched, cooked	wheat	tender stage	1.00	0.27	5.3120	5.3120	1.4342	6.2990	6.2990	1.7007	2.6410	2.6410	0.7131	3.5840	3.5840	0.9677
073	Shredded Wheat cereal	wheat		1.00	0.93	1.5150	1.5150	1.4090	2.7570	2.7570	2.5640	2.0860	2.0860	1.9400	2.8370	2.8370	2.6384
074	Raisin Bran cereal	wheat	assume no sugar on raisins	0.57	0.97	1.2310	0.7017	0.6806	1.3110	0.7473	0.7249	2.3010	1.3116	1.2722	4.3480	2.4784	2.4040
133	onion rings, breaded & fried, frozen, commercial,heated	wheat		0.11	0.88	0.5200	0.0572	0.0503	0.9270	0.1020	0.0897	0.1450	0.0160	0.0140	0.1120	0.0123	0.0108
139	scalloped potatoes, homemade	wheat		0.07	0.88	5.1640	0.3615	0.3181	7.4240	0.5197	0.4573	5.3500	0.3751	0.3301	7.6840	0.5379	0.4733
142	spaghetti with meat sauce, homemade	wheat	noodles	0.33	0.88	15.5010	5.1153	4.5015	23.9170	7.8926	6.9455	8.9560	2.9555	2.6008	11.0850	3.6581	3.2191
143	beef and vegetable stew, homemade	wheat		0.03	0.88	8.0740	0.2422	0.2132	11.3150	0.3395	0.2987	10.9010	0.3270	0.2878	14.5170	0.4355	0.3832
144	pizza, cheese, frozen, commercial, heated	wheat		0.25	0.88	9.2070	2.3018	2.0255	13.5180	3.3795	2.9740	2.0030	0.5008	0.4407	2.2310	0.5578	0.4908
146	macaroni and cheese, prepared from box mix	wheat	noodles	0.29	0.88	7.4000	2.1460	1.8885	8.6990	2.5227	2.2200	5.1060	1.4807	1.3031	4.4730	1.2972	1.1415
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	wheat		0.34	0.65	10.4090	3.5391	2.3004	22.2150	7.5531	4.9095	3.3800	1.1492	0.7470	6.1860	2.1032	1.3671
148	meatloaf, beef, homemade	wheat		0.19	0.88	5.5950	1.0631	0.9355	12.2880	2.3347	2.0546	4.3420	0.8250	0.7260	7.0660	1.3425	1.1814
149	spaghetti in tomato sauce, canned	wheat	noodles	0.77	0.18	4.1410	3.1886	0.5739	4.2160	3.2463	0.5843	1.8750	1.4438	0.2599	3.2770	2.5233	0.4542
150	chicken noodle casserole, homemade	wheat	noodles	0.39	0.29	2.3550	0.9185	0.2664	5.2490	2.0471	0.5937	2.1530	0.8397	0.2435	1.7760	0.6926	0.2009
151	lasagne, homemade	wheat	noodles	0.40	0.30	3.0440	1.2176	0.3653	5.1430	2.0572	0.6172	1.5230	0.6092	0.1828	1.9470	0.7788	0.2336
152	potpie, frozen, commercial, chicken, oven heated	wheat		0.30	0.88	1.3440	0.4032	0.3548	2.0880	0.6264	0.5512	1.4940	0.4482	0.3944	1.3920	0.4176	0.3675
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	wheat		0.33	0.88	1.3990	0.4617	0.4063	1.2230	0.4036	0.3552	1.2620	0.4165	0.3665	1.9460	0.6422	0.5651
155	chicken noodle soup, canned, reconstituted with water	wheat		0.04	0.88	7.0920	0.2837	0.2496	7.5110	0.3004	0.2644	8.2750	0.3310	0.2913	14.2020	0.5681	0.4999
157	vegetable beef soup, canned, reconstituted with water	wheat		0.03	0.88	5.8700	0.1761	0.1550	15.0990	0.4530	0.3986	21.8390	0.6552	0.5765	20.5360	0.6161	0.5422
160	white sauce, medium, homemade	wheat		0.08	0.88	0.9790	0.0783	0.0689	1.7100	0.1368	0.1204	0.7340	0.0587	0.0517	1.8370	0.1470	0.1293
176	ice cream sandwich	wheat		0.73	0.63	0.6610	0.4825	0.3040	0.5560	0.4059	0.2557	0.3690	0.2694	0.1697	0.5840	0.4263	0.2686
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	wheat		0.25	0.63	3.3420	0.8355	0.5264	5.9130	1.4783	0.9313	1.9840	0.4960	0.3125	3.4690	0.8673	0.5464
179	yellow cake prep. from mix w/white icing prep. from mix	wheat		0.25	0.63	5.5890	1.3973	0.8803	8.9790	2.2448	1.4142	6.8930	1.7233	1.0856	8.2560	2.0640	1.3003
180	coffeecake, (ready-to-eat/frozen)	wheat		0.24	0.88	0.7440	0.1786	0.1571	1.3960	0.3350	0.2948	1.1990	0.2878	0.2532	1.4900	0.3576	0.3147
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	wheat		0.37	0.88	3.6910	1.3657	1.2018	5.6830	2.1027	1.8504	2.3070	0.8536	0.7512	4.7270	1.7490	1.5391
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	wheat		0.46	0.88	2.0300	0.9338	0.8217	3.6500	1.6790	1.4775	2.5210	1.1597	1.0205	3.1590	1.4531	1.2788
183	cookies, chocolate chip	wheat		0.48	0.97	3.7510	1.8005	1.7465	4.7230	2.2670	2.1990	3.0840	1.4803	1.4359	4.5760	2.1965	2.1306
184	cookies, sandwich type, chocolate w/white cream filling	wheat		0.48	0.97	1.6480	0.7910	0.7673	2.7150	1.3032	1.2641	1.0520	0.5050	0.4898	2.4320	1.1674	1.1323
185	apple pie, frozen, heated	wheat		0.33	0.88	4.8960	1.6157	1.4218	7.3590	2.4285	2.1371	6.2820	2.0731	1.8243	8.7150	2.8760	2.5308
186	pumpkin pie, frozen, heated	wheat		0.30	0.88	3.3030	0.9909	0.8720	5.5980	1.6794	1.4779	4.8070	1.4421	1.2690	5.2000	1.5600	1.3728
204	infant mixed cereal, prepared from dry with whole milk	wheat		0.18	0.92	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
214	chicken and noodles, (st./jr.)	wheat		0.30	0.30	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
215	tomatoes, beef and macaroni, (st./jr.)	wheat		0.11	0.88	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
222	corn, creamed, (st./jr.)	wheat	strained	1.00	0.16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
228	bananas and pineapple with tapioca, (st./jr.)	wheat		0.21	0.88	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table A1-3: Part A - Crops

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
229	prunes/plums with tapioca, (st./jr.)	wheat		0.21	0.88	4.479	0.9406	0.8277	0.3560	0.0748	0.0658	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
233	fruit dessert with tapioca, any fruit, (st./jr.)	wheat		0.21	0.88	4.392	0.9223	0.8116	0.4020	0.0844	0.0743	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
234	dutch apple/apple betty, (st./jr.)	wheat		0.04	0.88	8.041	0.3216	0.2830	0.0600	0.0024	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		wheat-total					42.6161	27.6020		57.1387	42.2344		86.0392	61.5025		127.8282	97.2110
039	pork and beans, canned	corn	corn syrup	0.07	0.99	1.024	0.0717	0.0710	4.5930	0.3215	0.3183	5.5360	0.3875	0.3836	11.1670	0.7817	0.7739
039	pork and beans, canned	corn	starch	0.04	0.99	1.024	0.0410	0.0406	4.5930	0.1837	0.1819	5.5360	0.2214	0.2192	11.1670	0.4467	0.4422
053	corn grits(hominy grits), enriched, cooked	corn	degermed	1.00	0.13	3.691	3.6910	0.4798	5.1170	5.1170	0.6652	4.2150	4.2150	0.5480	6.4300	6.4300	0.8359
054	corn, (fresh/frozen), boiled	corn	fresh, 5" by 1 3/4" ear	1.00	0.26	0.375	0.3750	0.0975	4.0130	4.0130	1.0434	5.2460	5.2460	1.3640	8.0370	8.0370	2.0896
055	corn, canned	corn	wet packed, drain solids	1.00	0.24	0.416	0.4160	0.0998	3.2950	3.2950	0.7908	4.5880	4.5880	1.1011	7.2220	7.2220	1.7333
056	corn, cream style, canned	corn		1.00	0.24	0.680	0.6800	0.1632	1.6970	1.6970	0.4073	4.1060	4.1060	0.9854	1.8360	1.8360	0.4406
057	popcorn, popped in oil	corn	large kernal, salt added	0.78	0.94	0.150	0.1170	0.1100	0.6970	0.5437	0.5110	1.1870	0.9259	0.8703	1.5000	1.1700	1.0998
060	cornbread, southern style, homemade	corn	corn meal	0.31	0.89	0.877	0.2719	0.2420	3.2590	1.0103	0.8992	4.4320	1.3739	1.2228	6.8760	2.1316	1.8971
063	tortilla, flour	corn	yellow, untreated	1.00	0.88	0.403	0.4030	0.3546	1.2880	1.2880	1.1334	2.2210	2.2210	1.9545	3.5570	3.5570	3.1302
067	corn chips	corn		0.80	0.95	0.106	0.0848	0.0806	1.3760	1.1008	1.0458	2.8940	2.3152	2.1994	2.3540	1.8832	1.7890
068	pancakes made from mix w/addition of egg, milk and oil	corn		0.04	0.90	1.075	0.0430	0.0387	5.8330	0.2333	0.2100	5.7260	0.2290	0.2061	8.0120	0.3205	0.2884
071	corn flakes	corn		1.00	0.96	0.577	0.5770	0.5539	2.6480	2.6480	2.5421	3.2350	3.2350	3.1056	6.1810	6.1810	5.9338
072	fruit flavored, presweetened cereal	corn	assume Fruit Loops	0.81	0.99	0.166	0.1345	0.1331	2.7390	2.2186	2.1964	1.4610	1.1834	1.1716	3.3300	2.6973	2.6703
077	oat ring. unsweetened cereal	corn	corn meal	0.45	0.98	0.428	0.1926	0.1887	2.0010	0.9005	0.8824	1.2820	0.5769	0.5654	3.9890	1.7951	1.7591
129	vegetables, mixed, canned	corn		0.19	0.18	1.064	0.2022	0.0364	1.8120	0.3443	0.0620	2.7320	0.5191	0.0934	3.5330	0.6713	0.1208
153	pork chow mein, homemade	corn	cornstarch	0.01	0.89	0.321	0.0032	0.0029	0.8090	0.0081	0.0072	2.0730	0.0207	0.0184	3.1190	0.0312	0.0278
155	chicken noodle soup, canned, reconstituted with water	corn	corn syrup	0.01	0.89	6.835	0.0684	0.0608	17.8080	0.1781	0.1585	12.6120	0.1261	0.1122	7.0820	0.0708	0.0630
156	tomato soup, canned, reconstituted with whole milk	corn	corn syrup	0.25	0.99	3.052	0.7630	0.7554	5.7570	1.4393	1.4249	6.0000	1.5000	1.4850	5.4890	1.3723	1.3585
157	vegetable beef soup, canned, reconstituted with water	corn	corn syrup	0.01	0.99	5.792	0.0579	0.0573	16.1960	0.1620	0.1603	12.1130	0.1211	0.1199	13.2320	0.1323	0.1310
157	vegetable beef soup, canned, reconstituted with water	corn	corn starch	0.02	0.89	5.792	0.1158	0.1031	16.1960	0.3239	0.2883	12.1130	0.2423	0.2156	13.2320	0.2646	0.2355
159	gravy, brown, from mix	corn	corn starch	0.01	0.89	1.891	0.0189	0.0168	3.5130	0.0351	0.0313	6.1630	0.0616	0.0549	7.3600	0.0736	0.0655
170	syrup, pancake, bottled	corn	corn syrup	0.22	0.73	0.561	0.1234	0.0901	2.4540	0.5399	0.3941	3.6300	0.7986	0.5830	5.9630	1.3119	0.9577
232	pudding/custard, any flavor, (st./jr.)	corn	corn starch	0.03	0.89	8.326	0.2498	0.2223	0.0150	0.0005	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		corn-total					8.7010	3.9986		27.6014	15.3541		34.2138	18.5795		48.4169	27.8431
050	rice, white, enriched, cooked	rice		1.00	0.27	4.334	4.3340	1.1702	12.9310	12.9310	3.4914	16.7320	16.7320	4.5176	19.5040	19.5040	5.2661
075	crisped rice cereal	rice		0.71	0.88	0.418	0.2968	0.2612	1.7490	1.2418	1.0928	0.9910	0.7036	0.6192	2.1960	1.5592	1.3721
216	turkey and rice, (st./jr.)	rice		0.80	0.17	4.200	3.3600	0.5712	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
232	pudding/custard, any flavor, (st./jr.)	rice	rice starch	0.03	0.89	8.326	0.2498	0.2223	0.0150	0.0005	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		rice-total					8.2406	2.2249		14.1732	4.5045		17.4356	5.1368		21.0632	6.6381
051	oatmeal, cooked	oats		1.00	0.13	12.252	12.2520	1.5928	12.1590	12.1590	1.5807	3.2260	3.2260	0.4194	5.8540	5.8540	0.7610
076	granola, with raisins	oats		0.61	0.88	0.204	0.1244	0.1095	0.2850	0.1738	0.1530	0.2160	0.1318	0.1159	0.2940	0.1793	0.1578
077	oat ring. unsweetened cereal	oats		0.50	0.88	0.428	0.2140	0.1883	2.0010	1.0005	0.8804	1.2820	0.6410	0.5641	3.9890	1.9945	1.7552
217	oatmeal with applesauce and bananas, (st./jr.)	oats		0.13	0.88	16.077	2.0900	1.8392	0.3160	0.0411	0.0362	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		oats-total					14.6805	3.7298		13.3744	2.6502		3.9988	1.0994		8.0278	2.6740
064	rye bread	other grain	1/3 rye flour	0.12	0.88	0.082	0.0098	0.0087	0.6870	0.0824	0.0725	0.9140	0.1097	0.0965	0.7240	0.0869	0.0765
198	beer, canned	other grain	hop&barley-derived alcohol&solids	0.08	1.00	0.024	0.0019	0.0019	0.0570	0.0046	0.0046	0.0710	0.0057	0.0057	16.1190	1.2895	1.2895
		other grain-total					0.0118	0.0106		0.0870	0.0771		0.1154	0.1022		1.3764	1.3660
134	French fries, frozen, commercial, heated	potato	oven heated	0.92	0.18	2.475	2.2770	0.4099	13.5650	12.4798	2.2464	19.9540	18.3577	3.3044	31.2120	28.7150	5.1687
135	mashed potatoes w/marg. & milk, prepared from instant	potato	dried flakes	0.40	0.99	7.389	2.9556	2.9260	9.8790	3.9516	3.9121	15.0040	6.0016	5.9416	24.5260	9.8104	9.7123
136	boiled potato without peel	potato	peeled before cooking	1.00	0.17	2.623	2.6230	0.4459	6.5620	6.5620	1.1155	9.4950	9.4950	1.6142	8.2350	8.2350	1.4000

Table A1-3: Part A - Crops

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
229	prunes/plums with tapioca, (st./jr.)	wheat		0.21	0.88	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
233	fruit dessert with tapioca, any fruit, (st./jr.)	wheat		0.21	0.88	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
234	dutch apple/apple betty, (st./jr.)	wheat		0.04	0.88	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		wheat-total					70.5907	52.8166		103.6207	78.5058		59.7653	45.8331		83.7464	64.4170
039	pork and beans, canned	corn	corn syrup	0.07	0.99	5.5090	0.3856	0.3818	10.2340	0.7164	0.7092	4.9630	0.3474	0.3439	7.9010	0.5531	0.5475
039	pork and beans, canned	corn	starch	0.04	0.99	5.5090	0.2204	0.2182	10.2340	0.4094	0.4053	4.9630	0.1985	0.1965	7.9010	0.3160	0.3129
053	corn grits(hominy grits), enriched, cooked	corn	degermed	1.00	0.13	3.1300	3.1300	0.4069	3.7440	3.7440	0.4867	4.8180	4.8180	0.6263	6.3110	6.3110	0.8204
054	corn, (fresh/frozen), boiled	corn	fresh, 5" by 1 3/4" ear	1.00	0.26	5.8750	5.8750	1.5275	7.2770	7.2770	1.8920	5.7330	5.7330	1.4906	7.2770	7.2770	1.8920
055	corn, canned	corn	wet packed, drain solids	1.00	0.24	2.4600	2.4600	0.5904	5.0290	5.0290	1.2070	1.3410	1.3410	0.3218	2.2570	2.2570	0.5417
056	corn, cream style, canned	corn		1.00	0.24	1.6150	1.6150	0.3876	2.1940	2.1940	0.5266	1.4350	1.4350	0.3444	3.3980	3.3980	0.8155
057	popcorn, popped in oil	corn	large kernal, salt added	0.78	0.94	1.6900	1.3182	1.2391	1.4320	1.1170	1.0499	0.1250	0.0975	0.0917	0.2530	0.1973	0.1855
060	cornbread, southern style, homemade	corn	corn meal	0.31	0.89	3.8690	1.1994	1.0675	8.8500	2.7435	2.4417	8.3130	2.5770	2.2936	11.9270	3.6974	3.2907
063	tortilla, flour	corn	yellow, untreated	1.00	0.88	2.3060	2.3060	2.0293	3.9450	3.9450	3.4716	0.4000	0.4000	0.3520	0.9990	0.9990	0.8791
067	corn chips	corn		0.80	0.95	0.8090	0.6472	0.6148	2.4990	1.9992	1.8992	0.2080	0.1664	0.1581	0.5100	0.4080	0.3876
068	pancakes made from mix w/addition of egg, milk and oil	corn		0.04	0.90	4.4820	0.1793	0.1614	6.9760	0.2790	0.2511	3.6180	0.1447	0.1302	6.2960	0.2518	0.2267
071	corn flakes	corn		1.00	0.96	1.3480	1.3480	1.2941	1.4190	1.4190	1.3622	1.7930	1.7930	1.7213	2.9080	2.9060	2.7917
072	fruit flavored, presweetened cereal	corn	assume Fruit Loops	0.81	0.99	0.2600	0.2106	0.2085	1.9440	1.5746	1.5589	0.0670	0.0543	0.0537	0.0680	0.0551	0.0545
077	oat ring. unsweetened cereal	corn	corn meal	0.45	0.98	0.4670	0.2102	0.2059	0.9280	0.4176	0.4092	0.3450	0.1553	0.1521	0.2910	0.1309	0.1283
129	vegetables, mixed, canned	corn		0.19	0.18	5.9580	1.1320	0.2038	5.6230	1.0684	0.1923	6.8150	1.2949	0.2331	6.2630	1.1900	0.2142
153	pork chow mein, homemade	corn	cornstarch	0.01	0.89	3.8240	0.0382	0.0340	4.5130	0.0451	0.0402	2.9200	0.0292	0.0260	2.9040	0.0290	0.0258
155	chicken noodle soup, canned, reconstituted with water	corn	corn syrup	0.01	0.89	7.0920	0.0709	0.0631	7.5110	0.0751	0.0668	8.2750	0.0828	0.0736	14.2020	0.1420	0.1264
156	tomato soup, canned, reconstituted with whole milk	corn	corn syrup	0.25	0.99	10.8540	2.7135	2.6864	11.1120	2.7780	2.7502	11.7070	2.9268	2.8975	11.6200	2.9050	2.8759
157	vegetable beef soup, canned, reconstituted with water	corn	corn syrup	0.01	0.99	5.8700	0.0587	0.0581	15.0990	0.1510	0.1495	21.8390	0.2184	0.2162	20.5360	0.2054	0.2033
157	vegetable beef soup, canned, reconstituted with water	corn	corn starch	0.02	0.89	5.8700	0.1174	0.1045	15.0990	0.3020	0.2688	21.8390	0.4368	0.3887	20.5360	0.4107	0.3655
159	gravy, brown, from mix	corn	corn starch	0.01	0.89	3.6920	0.0369	0.0329	7.9410	0.0794	0.0707	4.1410	0.0414	0.0369	8.5360	0.0854	0.0760
170	syrup, pancake, bottled	corn	corn syrup	0.22	0.73	2.2130	0.4869	0.3554	3.5710	0.7856	0.5735	1.4880	0.3274	0.2390	3.0990	0.6818	0.4977
232	pudding/custard, any flavor, (st./jr.)	corn	corn starch	0.03	0.89	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		corn-total					25.7594	13.8710		38.1493	21.7827		24.6186	12.3873		34.4089	17.2590
050	rice, white, enriched, cooked	rice		1.00	0.27	15.8950	15.8950	4.2917	22.9430	22.9430	6.1946	12.4660	12.4660	3.3658	14.2960	14.2960	3.8599
075	crisped rice cereal	rice		0.71	0.88	0.7760	0.5510	0.4848	0.9410	0.6681	0.5879	1.0540	0.7483	0.6585	0.8580	0.6092	0.5361
216	turkey and rice, (st./jr.)	rice		0.80	0.17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
232	pudding/custard, any flavor, (st./jr.)	rice	rice starch	0.03	0.89	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		rice-total					16.4460	4.7765		23.6111	6.7825		13.2143	4.0244		14.9052	4.3960
051	oatmeal, cooked	oats		1.00	0.13	4.3800	4.3800	0.5694	2.0210	2.0210	0.2627	10.0390	10.0390	1.3051	13.5700	13.5700	1.7641
076	granola, with raisins	oats		0.61	0.88	0.5870	0.3581	0.3151	1.6410	1.0010	0.8809	0.7530	0.4593	0.4042	0.4600	0.2806	0.2469
077	oat ring. unsweetened cereal	oats		0.50	0.88	0.4670	0.2335	0.2055	0.9280	0.4640	0.4083	0.3450	0.1725	0.1518	0.2910	0.1455	0.1280
217	oatmeal with applesauce and bananas, (st./jr.)	oats		0.13	0.88	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		oats-total					4.9716	1.0900		3.4860	1.5519		10.6708	1.8611		13.9961	2.1391
064	rye bread	other grain	1/3 rye flour	0.12	0.88	0.9470	0.1136	0.1000	0.9450	0.1134	0.0998	1.0140	0.1217	0.1071	0.8380	0.1006	0.0885
198	beer, canned	other grain	hop&barley-derived alcohol&solids	0.08	1.00	34.5910	2.7673	2.7673	299.2020	23.9362	23.9362	9.2910	0.7433	0.7433	98.4790	7.8783	7.8783
		other grain-total					2.8809	2.8673		24.0496	24.0360		0.8650	0.8504		7.9789	7.9668
134	French fries, frozen, commercial, heated	potato	oven heated	0.92	0.18	15.7010	14.4449	2.6001	32.7500	30.1300	5.4234	6.0180	5.5366	0.9966	14.5180	13.3566	2.4042
135	mashed potatoes w/marg. & milk, prepared from instant	potato	dried flakes	0.40	0.99	11.6100	4.6440	4.5976	18.8350	7.5340	7.4587	10.4050	4.1620	4.1204	17.0150	6.8060	6.7379
136	boiled potato without peel	potato	peeled before cooking	1.00	0.17	8.3530	8.3530	1.4200	11.7270	11.7270	1.9936	15.6040	15.6040	2.6527	19.8000	19.8000	3.3660

Table A1-3: Part A - Crops

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6 11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
137	baked potato with peel	potato	peeled after baking	1.00	0.25	0.601	0.6010	0.1563	3.1780	3.1780	0.7945	5.4200	5.4200	1.3550	4.8230	4.8230	1.2058
138	potato chips, commercial	potato		0.60	0.96	0.166	0.0996	0.0956	2.0570	1.2342	1.1848	4.1910	2.5146	2.4140	6.3520	3.8112	3.6588
139	scalloped potatoes, homemade	potato		0.55	0.26	1.023	0.5627	0.1463	2.0490	1.1270	0.2930	4.1450	2.2798	0.5927	5.8710	3.2291	0.8396
140	sweet potato, baked in skin	potato	peeled after baking	1.00	0.36	0.367	0.3670	0.1321	0.4530	0.4530	0.1631	0.9940	0.9940	0.3578	0.8080	0.8080	0.2909
141	sweet potato, candied, homemade	potato		0.55	0.26	0.095	0.0523	0.0136	0.3550	0.1953	0.0508	0.3220	0.1771	0.0460	0.9470	0.5209	0.1354
143	beef and vegetable stew, homemade	potato		0.17	0.20	2.838	0.4825	0.0965	5.7980	0.9857	0.1971	8.8880	1.5110	0.3022	10.8960	1.8523	0.3705
152	potpie, frozen, commercial, chicken, oven heated	potato		0.07	0.17	0.142	0.0099	0.0017	1.7610	0.1233	0.0210	1.4120	0.0988	0.0168	2.1170	0.1482	0.0252
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	potato		0.09	0.13	0.065	0.0059	0.0008	1.6920	0.1523	0.0198	1.3290	0.1196	0.0155	0.8830	0.0795	0.0103
157	vegetable beef soup, canned, reconstituted with water	potato		0.01	0.10	5.792	0.0579	0.0058	16.1960	0.1620	0.0162	12.1130	0.1211	0.0121	13.2320	0.1323	0.0132
221	sweet potatoes/yellow squash, (st./jr.)	potato	sweet potato strained	1.00	0.15	8.286	8.2860	1.2429	0.1280	0.1280	0.0192	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		potato-total					18.3803	5.6673		30.7320	10.0335		47.0903	15.9724		62.1648	22.8305
106	spinach, canned	leafy veg	drained	1.00	0.09	0.049	0.0490	0.0044	0.3480	0.3480	0.0313	0.3850	0.3850	0.0347	0.6660	0.6660	0.0599
107	spinach, (fresh/frozen), boiled	leafy veg	fresh	1.00	0.08	0.197	0.1970	0.0158	0.5860	0.5860	0.0469	0.5900	0.5900	0.0472	1.9370	1.9370	0.1550
108	collards, (fresh/frozen), boiled	leafy veg	fresh, leaves without stems	1.00	0.10	0.401	0.4010	0.0401	0.5060	0.5060	0.0506	0.7200	0.7200	0.0720	1.5530	1.5530	0.1553
109	lettuce, raw	leafy veg	Iceberg lettuce	1.00	0.04	0.125	0.1250	0.0050	2.6190	2.6190	0.1048	13.4960	13.4960	0.5398	12.2470	12.2470	0.4899
110	cabbage, boiled from raw	leafy veg		1.00	0.06	0.236	0.2380	0.0143	0.6670	0.6670	0.0400	1.8030	1.8030	0.1082	1.7650	1.7650	0.1059
111	coleslaw with dressing, homemade	leafy veg	1/2 tsp celery seed added	0.50	0.08	0.001	0.0005	0.0000	0.3470	0.1735	0.0139	1.9620	0.9810	0.0785	1.9830	0.9915	0.0793
112	sauerkraut, canned	leafy veg	solids & liquids	1.00	0.07	0.030	0.0300	0.0021	0.0640	0.0640	0.0045	0.2690	0.2690	0.0188	0.7570	0.7570	0.0530
113	broccoli, (fresh/frozen), boiled	leafy veg		1.00	0.09	0.359	0.3590	0.0323	1.2540	1.2540	0.1129	1.4850	1.4850	0.1337	0.9080	0.9080	0.0817
114	celery, raw	leafy veg	Pascal type	1.00	0.06	0.030	0.0300	0.0018	0.1730	0.1730	0.0104	0.5460	0.5460	0.0328	0.3350	0.3350	0.0201
115	asparagus, (fresh/frozen), boiled	leafy veg	fresh, cuts & tips	1.00	0.06	0.045	0.0450	0.0027	0.1710	0.1710	0.0103	0.1190	0.1190	0.0071	0.2650	0.2650	0.0159
116	cauliflower, (fresh/frozen), boiled	leafy veg	raw, flower buds	1.00	0.07	0.000	0.0000	0.0000	0.3870	0.3870	0.0271	0.4040	0.4040	0.0283	0.3030	0.3030	0.0212
142	spaghetti with meat sauce, homemade	leafy veg	parsley	0.01	0.15	4.786	0.0479	0.0072	16.4100	0.1641	0.0246	17.4770	0.1748	0.0262	33.5700	0.3357	0.0504
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	leafy veg	lettuce	0.01	0.05	0.559	0.0056	0.0003	4.5740	0.0457	0.0023	13.6950	0.1370	0.0068	18.7500	0.1875	0.0094
220	mixed vegetables/garden vegetables, (st./jr.)	leafy veg	strained	1.00	0.10	5.532	5.5320	0.5532	0.0600	0.0600	0.0060	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
224	spinach, creamed, (st./jr.)	leafy veg	strained	1.00	0.10	1.588	1.5880	0.1588	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		leafy veg-total					8.6480	0.8380		7.2183	0.4854		21.1097	1.1341		22.2507	1.2970
038	pinto beans, boiled from dried	legume veg		1.00	0.34	1.004	1.0040	0.3414	3.8500	3.8500	1.3090	5.7610	5.7610	1.9587	9.2480	9.2480	3.1443
039	pork and beans, canned	legume veg		0.40	0.31	1.024	0.4096	0.1270	4.5930	1.8372	0.5695	5.5360	2.2144	0.6865	11.1670	4.4668	1.3847
040	cowpeas (blackeyed peas), boiled from dried	legume veg	drained	1.00	0.28	0.153	0.1530	0.0428	1.0940	1.0940	0.3063	1.3740	1.3740	0.3847	2.6280	2.6280	0.7358
041	lima beans, mature, boiled from dried	legume veg		1.00	0.34	0.024	0.0240	0.0082	0.4670	0.4670	0.1588	0.5430	0.5430	0.1846	0.7640	0.7640	0.2598
042	lima beans, immature, frozen, boiled	legume veg		1.00	0.26	0.215	0.2150	0.0559	0.5950	0.5950	0.1547	0.5750	0.5750	0.1495	0.6140	0.6140	0.1596
043	navy beans, boiled from dried	legume veg		1.00	0.31	0.024	0.0240	0.0074	0.5840	0.5840	0.1810	0.9540	0.9540	0.2957	2.7020	2.7020	0.8376
044	red beans, boiled from dried	legume veg		1.00	0.31	0.449	0.4490	0.1392	0.8160	0.8160	0.2530	2.0870	2.0870	0.6470	1.6810	1.6810	0.5211
045	peas, green, canned	legume veg	whole, drained	1.00	0.23	1.260	1.2600	0.2898	3.1920	3.1920	0.7342	2.9440	2.9440	0.6771	5.5410	5.5410	1.2744
046	peas, green, frozen, boiled	legume veg	drained	1.00	0.18	0.954	0.9540	0.1717	0.6660	0.6660	0.1199	0.8770	0.8770	0.1579	1.3970	1.3970	0.2515
121	beans, snap green, (fresh/frozen),boiled	legume veg	fresh	1.00	0.08	0.347	0.3470	0.0278	0.9050	0.9050	0.0724	1.2090	1.2090	0.0967	2.7570	2.7570	0.2206
122	beans, snap green, canned	legume veg	drained & cut	1.00	0.08	1.585	1.5850	0.1268	3.2340	3.2340	0.2587	4.6540	4.6540	0.3723	6.6180	6.6180	0.5294
129	vegetables, mixed, canned	legume veg	green beans	0.23	0.18	1.064	0.2447	0.0440	1.8120	0.4168	0.0750	2.7320	0.6284	0.1131	3.5330	0.8126	0.1463
129	vegetables, mixed, canned	legume veg	lima beans	0.09	0.18	1.064	0.0958	0.0172	1.8120	0.1631	0.0294	2.7320	0.2459	0.0443	3.5330	0.3180	0.0572
129	vegetables, mixed, canned	legume veg	peas	0.37	0.18	1.064	0.3937	0.0709	1.8120	0.6704	0.1207	2.7320	1.0108	0.1820	3.5330	1.3072	0.2353
145	chili con carne, beef and beans, canned	legume veg	beans	0.33	0.15	0.938	0.3095	0.0464	2.2260	0.7346	0.1102	7.8950	2.6054	0.3908	14.3070	4.7213	0.7082
152	potpie, frozen, commercial, chicken, oven heated	legume veg	pea	0.09	0.12	0.142	0.0128	0.0015	1.7610	0.1585	0.0190	1.4120	0.1271	0.0152	2.1170	0.1905	0.0229
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	legume veg	assume peas or beans	0.07	0.21	0.065	0.0046	0.0010	1.6920	0.1184	0.0249	1.3290	0.0930	0.0195	0.8830	0.0618	0.0130
157	vegetable beef soup, canned, reconstituted with water	legume veg		0.01	0.12	5.792	0.0579	0.0070	16.1960	0.1620	0.0194	12.1130	0.1211	0.0145	13.2320	0.1323	0.0159
208	high meat (chicken/turkey) and vegetables, (st./jr.)	legume veg	peas, beans	0.28	0.09	6.200	1.7360	0.1562	0.2250	0.0630	0.0057	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
209	high meat beef and vegetables, (st./jr.)	legume veg	peas, beans	0.28	0.09	9.236	2.5861	0.2327	0.2070	0.0580	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table A1-3: Part A - Crops

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
137	baked potato with peel	potato	peeled after baking	1.00	0.25	7.2030	7.2030	1.8008	8.1670	8.1670	2.0418	7.2190	7.2190	1.8048	8.3210	8.3210	2.0803
138	potato chips, commercial	potato		0.60	0.96	2.1940	1.3164	1.2637	4.0370	2.4222	2.3253	0.4490	0.2694	0.2586	0.5530	0.3318	0.3185
139	scalloped potatoes, homemade	potato		0.55	0.26	5.1640	2.8402	0.7385	7.4240	4.0832	1.0616	5.3580	2.9469	0.7662	7.6840	4.2262	1.0988
140	sweet potato, baked in skin	potato	peeled after baking	1.00	0.36	1.1030	1.1030	0.3971	1.2700	1.2700	0.4572	2.5730	2.5730	0.9263	2.4960	2.4960	0.8986
141	sweet potato, candied, homemade	potato		0.55	0.26	0.5620	0.3091	0.0804	1.0080	0.5544	0.1441	0.6090	0.3350	0.0871	0.5930	0.3262	0.0848
143	beef and vegetable stew, homemade	potato		0.17	0.20	8.0740	1.3726	0.2745	11.3150	1.9236	0.3847	10.9010	1.8532	0.3706	14.5170	2.4679	0.4936
152	potpie, frozen, commercial, chicken, oven heated	potato		0.07	0.17	1.3440	0.0941	0.0160	2.0880	0.1462	0.0248	1.4940	0.1046	0.0178	1.3920	0.0974	0.0166
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	potato		0.09	0.13	1.3990	0.1259	0.0164	1.2230	0.1101	0.0143	1.2620	0.1136	0.0148	1.9460	0.1751	0.0228
157	vegetable beef soup, canned, reconstituted with water	potato		0.01	0.10	5.8700	0.0587	0.0059	15.0990	0.1510	0.0151	21.8390	0.2184	0.0218	20.5360	0.2054	0.0205
221	sweet potatoes/yellow squash, (st./jr.)	potato	sweet potato strained	1.00	0.15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		potato-total					41.8649	13.2108		68.2186	21.3447		40.9355	12.0376		58.6095	17.5425
106	spinach, canned	leafy veg	drained	1.00	0.09	0.8310	0.8310	0.0748	0.8750	0.8750	0.0788	5.7240	5.7240	0.5152	1.4180	1.4180	0.1276
107	spinach, (fresh/frozen), boiled	leafy veg	fresh	1.00	0.08	2.4850	2.4850	0.1988	2.4050	2.4050	0.1924	3.0170	3.0170	0.2414	2.5390	2.5390	0.2031
108	collards, (fresh/frozen), boiled	leafy veg	fresh, leaves without stems	1.00	0.10	0.9030	0.9030	0.0903	1.3490	1.3490	0.1349	2.7480	2.7480	0.2748	3.0170	3.0170	0.3017
109	lettuce, raw	leafy veg	Iceberg lettuce	1.00	0.04	23.5400	23.5400	0.9416	23.3810	23.3810	0.9352	20.8850	20.8850	0.8354	21.8370	21.8370	0.8735
110	cabbage, boiled from raw	leafy veg		1.00	0.06	3.0360	3.0360	0.1822	2.6030	2.6030	0.1562	4.1620	4.1620	0.2497	3.7270	3.7270	0.2236
111	coleslaw with dressing, homemade	leafy veg	1/2 tsp celery seed added	0.50	0.08	2.4220	1.2110	0.0969	2.8870	1.4435	0.1155	2.6740	1.3370	0.1070	3.2530	1.6265	0.1301
112	sauerkraut, canned	leafy veg	solids & liquids	1.00	0.07	0.6560	0.6560	0.0459	1.5530	1.5530	0.1087	0.9150	0.9150	0.0641	1.4850	1.4850	0.1040
113	broccoli, (fresh/frozen), boiled	leafy veg		1.00	0.09	3.9540	3.9540	0.3559	2.7950	2.7950	0.2516	2.4520	2.4520	0.2207	2.8240	2.8240	0.2542
114	celery, raw	leafy veg	Pascal type	1.00	0.06	0.8180	0.8180	0.0491	0.6210	0.6210	0.0373	1.3670	1.3670	0.0820	1.8480	1.8480	0.1109
115	asparagus, (fresh/frozen), boiled	leafy veg	fresh, cuts & tips	1.00	0.06	0.8050	0.8050	0.0483	0.7570	0.7570	0.0454	1.3270	1.3270	0.0796	1.7440	1.7440	0.1046
116	cauliflower, (fresh/frozen), boiled	leafy veg	raw, flower buds	1.00	0.07	0.8310	0.8310	0.0582	0.7120	0.7120	0.0498	1.3800	1.3800	0.0966	1.0020	1.0020	0.0701
142	spaghetti with meat sauce, homemade	leafy veg	parsley	0.01	0.15	15.5010	0.1550	0.0233	23.9170	0.2392	0.0359	8.9560	0.0896	0.0134	11.0850	0.1109	0.0166
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	leafy veg	lettuce	0.01	0.05	10.4090	0.1041	0.0052	22.2150	0.2222	0.0111	3.3800	0.0338	0.0017	6.1860	0.0619	0.0031
220	mixed vegetables/garden vegetables, (st./jr.)	leafy veg	strained	1.00	0.10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
224	spinach, creamed, (st./jr.)	leafy veg	strained	1.00	0.10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		leafy veg-total					39.3291	2.1703		38.9558	2.1527		45.4374	2.7815		43.2402	2.5232
038	pinto beans, boiled from dried	legume veg		1.00	0.34	7.8260	7.8260	2.6608	10.6400	10.6400	3.6176	4.6890	4.6890	1.5943	7.3700	7.3700	2.5058
039	pork and beans, canned	legume veg		0.40	0.31	5.5090	2.2036	0.6831	10.2340	4.0936	1.2690	4.9630	1.9852	0.6154	7.9010	3.1604	0.9797
040	cowpeas (blackeyed peas), boiled from dried	legume veg	drained	1.00	0.28	1.6690	1.6690	0.4673	3.3560	3.3560	0.9397	2.2650	2.2650	0.6342	3.1180	3.1180	0.8730
041	lima beans, mature, boiled from dried	legume veg		1.00	0.34	0.4090	0.4090	0.1391	0.8230	0.8230	0.2798	1.1370	1.1370	0.3866	1.5470	1.5470	0.5260
042	lima beans, immature, frozen, boiled	legume veg		1.00	0.26	1.2820	1.2820	0.3333	1.4310	1.4310	0.3721	1.8340	1.8340	0.4768	2.0690	2.0690	0.5379
043	navy beans, boiled from dried	legume veg		1.00	0.31	0.7100	0.7100	0.2201	2.2830	2.2830	0.7077	1.3620	1.3620	0.4222	1.3900	1.3900	0.4309
044	red beans, boiled from dried	legume veg		1.00	0.31	1.3960	1.3960	0.4328	2.5540	2.5540	0.7917	1.3250	1.3250	0.4108	1.4460	1.4460	0.4483
045	peas, green, canned	legume veg	whole, drained	1.00	0.23	5.3190	5.3190	1.2234	5.8940	5.8940	1.3556	5.5470	5.5470	1.2758	8.1660	8.1660	1.8782
046	peas, green, frozen, boiled	legume veg	drained	1.00	0.18	1.6710	1.6710	0.3008	1.3990	1.3990	0.2518	2.2240	2.2240	0.4003	1.6310	1.6310	0.2936
121	beans, snap green, (fresh/frozen),boiled	legume veg	fresh	1.00	0.08	2.3480	2.3480	0.1878	3.0360	3.0360	0.2429	3.5070	3.5070	0.2806	4.6870	4.6870	0.3750
122	beans, snap green, canned	legume veg	drained & cut	1.00	0.08	2.2520	2.2520	0.1802	5.7050	5.7050	0.4564	6.8030	6.8030	0.5442	7.9950	7.9950	0.6396
129	vegetables, mixed, canned	legume veg	green beans	0.23	0.18	5.9580	1.3703	0.2467	5.6230	1.2933	0.2328	6.8150	1.5675	0.2821	6.2630	1.4405	0.2593
129	vegetables, mixed, canned	legume veg	lima beans	0.09	0.18	5.9580	0.5362	0.0965	5.6230	0.5061	0.0911	6.8150	0.6134	0.1104	6.2630	0.5637	0.1015
129	vegetables, mixed, canned	legume veg	peas	0.37	0.18	5.9580	2.2045	0.3968	5.6230	2.0805	0.3745	6.8150	2.5216	0.4539	6.2630	2.3173	0.4171
145	chili con carne, beef and beans, canned	legume veg	beans	0.33	0.15	5.3410	1.7625	0.2644	14.3690	4.7418	0.7113	4.7300	1.5609	0.2341	9.8050	3.2357	0.4853
152	potpie, frozen, commercial, chicken, oven heated	legume veg	pea	0.09	0.12	1.3440	0.1210	0.0145	2.0880	0.1879	0.0226	1.4940	0.1345	0.0161	1.3920	0.1253	0.0150
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	legume veg	assume peas or beans	0.07	0.21	1.3990	0.0979	0.0206	1.2230	0.0856	0.0180	1.2620	0.0883	0.0186	1.9460	0.1362	0.0286
157	vegetable beef soup, canned, reconstituted with water	legume veg		0.01	0.12	5.8700	0.0587	0.0070	15.0990	0.1510	0.0181	21.8390	0.2184	0.0262	20.5360	0.2054	0.0246
208	high meat (chicken/turkey) and vegetables, (st./jr.)	legume veg	peas, beans	0.28	0.09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
209	high meat beef and vegetables, (st./jr.)	legume veg	peas, beans	0.28	0.09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table A1-3: Part A - Crops

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
210	high meat ham and vegetables, (st./jr.)	legume veg		0.27	0.09	3.303	0.8918	0.0803	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
211	vegetables with beef, (st./jr.)	legume veg	peas, beans	0.40	0.09	12.717	5.0868	0.4578	0.1470	0.0588	0.0053	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
212	vegetables with (trukey/chicken), (st./jr.)	legume veg	peas, beans	0.40	0.09	5.412	2.1648	0.1948	0.0540	0.0216	0.0019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
213	vegetables with (bacon/ham), (st./jr.)	legume veg	peas, beans	0.37	0.09	8.112	3.0014	0.2701	0.1140	0.0422	0.0038	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
219	green beans, (st./jr.)	legume veg	strained	1.00	0.08	6.124	6.1240	0.4899	0.2020	0.2020	0.0162	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
223	peas, (st./jr.)	legume veg	strained	1.00	0.13	3.212	3.2120	0.4015	0.0240	0.0240	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		legume veg-total					32.3465	3.8094		20.1335	4.5571		28.0241	6.3902		45.9605	10.5176
127	carrots, raw	root veg	pared, with crown & tip	1.00	0.12	1.226	1.2260	0.1471	2.4000	2.4000	0.2880	1.3620	1.3620	0.1634	2.9640	2.9640	0.3557
128	onion, raw	root veg	mature, chopped	1.00	0.11	0.083	0.0830	0.0091	0.2210	0.2210	0.0243	2.6470	2.6470	0.2912	1.7550	1.7550	0.1931
129	vegetables, mixed, canned	root veg	carrots	0.12	0.18	1.064	0.1277	0.0230	1.8120	0.2174	0.0391	2.7320	0.3278	0.0590	3.5330	0.4240	0.0763
431	beets, canned	root veg	drained	1.00	0.11	0.019	0.0190	0.0021	0.3370	0.3370	0.0371	0.7330	0.7330	0.0806	0.4130	0.4130	0.0454
132	radish, raw	root veg		1.00	0.05	0.000	0.0000	0.0000	0.0370	0.0370	0.0019	0.2730	0.2730	0.0137	0.1360	0.1360	0.0068
133	onion rings, breaded & fried, frozen, commercial,heated	root veg		0.66	0.72	0.050	0.0330	0.0238	0.0970	0.0640	0.0461	0.6870	0.4534	0.3265	1.8700	1.2342	0.8886
139	scalloped potatoes, homemade	root veg	onion	0.02	0.11	1.023	0.0205	0.0023	2.0490	0.0410	0.0045	4.1450	0.0829	0.0091	5.8710	0.1174	0.0129
142	spaghetti with meat sauce, homemade	root veg	onion	0.01	0.14	4.786	0.0479	0.0067	16.4100	0.1641	0.0230	17.4770	0.174[illegible]	0.0245	33.5700	0.3357	0.0470
143	beef and vegetable stew, homemade	root veg	carrot	0.16	0.12	2.838	0.4541	0.0545	5.7980	0.9277	0.1113	8.8880	1.4221	0.1706	10.8960	1.7434	0.2092
145	chili con carne, beef and beans, canned	root veg	onions	0.12	0.15	0.938	0.1126	0.0169	2.2260	0.2671	0.0401	7.8950	0.9474	0.1421	14.3070	1.7168	0.2575
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	root veg	onion	0.01	0.10	0.559	0.0056	0.0006	4.5740	0.0457	0.0046	13.6950	0.1370	0.0137	18.7500	0.1875	0.0188
148	meatloaf, beef, homemade	root veg	onion	0.02	0.11	1.193	0.0239	0.0026	3.9830	0.0797	0.0088	6.4960	0.1299	0.0143	10.3690	0.2074	0.0228
152	potpie, frozen, commercial, chicken, oven heated	root veg	carrot	0.03	0.09	0.142	0.0043	0.0004	1.7610	0.0528	0.0048	1.4120	0.0424	0.0038	2.1170	0.0635	0.0057
208	high meat (chicken/turkey) and vegetables, (st./jr.)	root veg	carrot	0.28	0.14	6.200	1.7360	0.2430	0.2250	0.0630	0.0088	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
209	high meat beef and vegetables, (st./jr.)	root veg	carrot	0.29	0.14	9.236	2.6784	0.3750	0.2070	0.0600	0.0084	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
210	high meat ham and vegetables, (st./jr.)	root veg	carrot	0.28	0.14	3.303	0.9248	0.1295	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
211	vegetables with beef, (st./jr.)	root veg	carrot	0.40	0.14	12.717	5.0868	0.7122	0.1470	0.0588	0.0082	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
212	vegetables with (trukey/chicken), (st./jr.)	root veg	carrot	0.40	0.14	5.412	2.1648	0.3031	0.0540	0.0216	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
213	vegetables with (bacon/ham), (st./jr.)	root veg	carrot	0.37	0.14	8.112	3.0014	0.4202	0.1140	0.0422	0.0059	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
218	carrots, (st./jr.)	root veg	strained	1.00	0.08	7.101	7.1010	0.5681	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		root veg-total					24.8507	3.0400		5.1002	0.6678		8.7326	1.3125		11.2979	2.1398
039	pork and beans, canned	garden fruit	tomato	0.40	0.06	1.024	0.4096	0.0246	4.5930	1.8372	0.1102	5.5360	2.2144	0.1329	11.1670	4.4668	0.2680
097	avocado, raw	garden fruit		0.93	0.16	0.017	0.0158	0.0025	0.1120	0.1042	0.0167	0.5220	0.4855	0.0777	0.0550	0.0512	0.0082
097	avocado, raw	garden fruit	avocado oil	0.07	1.00	0.017	0.0012	0.0012	0.1120	0.0078	0.0078	0.5220	0.0365	0.0365	0.0550	0.0039	0.0039
117	tomato, raw	garden fruit		1.00	0.06	0.558	0.5580	0.0335	3.9440	3.9440	0.2366	9.5000	9.5000	0.5700	9.7820	9.7820	0.5869
118	tomato juice, canned	garden fruit		1.00	0.06	0.131	0.1310	0.0079	1.0050	1.0050	0.0603	0.8880	0.8880	0.0533	1.6320	1.6320	0.0979
119	tomato sauce, canned	garden fruit	only spices, no sugar added	1.00	0.11	0.154	0.1540	0.0169	1.7770	1.7770	0.1955	1.8240	1.8240	0.2006	2.9480	2.9480	0.3243
120	tomatoes, canned	garden fruit	solids & liquids	1.00	0.06	0.000	0.0000	0.0000	0.1520	0.1520	0.0091	0.1540	0.1540	0.0092	0.3350	0.3350	0.0201
123	cucumber, raw, pared	garden fruit		1.00	0.05	0.144	0.1440	0.0072	0.7610	0.7610	0.0381	1.7300	1.7300	0.0865	0.9600	0.9600	0.0480
124	squash, summer, (fresh/frozen), boiled	garden fruit		1.00	0.04	0.059	0.0590	0.0024	0.4030	0.4030	0.0161	0.5610	0.5610	0.0224	0.8290	0.8290	0.0332
125	sweet pepper, green, raw	garden fruit		1.00	0.07	0.007	0.0070	0.0005	0.0650	0.0650	0.0046	0.2760	0.2760	0.0193	0.6520	0.6520	0.0456
126	squash, winter (Hubbard/acorn), (raw/frozen), boiled	garden fruit	all varieties, baked	1.00	0.19	0.653	0.6530	0.1241	0.2260	0.2260	0.0429	0.4890	0.4890	0.0929	0.0270	0.0270	0.0051
142	spaghetti with meat sauce, homemade	garden fruit	tomato	0.06	0.10	4.786	0.2872	0.0287	16.4100	0.9846	0.0985	17.4770	1.0486	0.1049	33.5700	2.0142	0.2014
144	pizza, cheese, frozen, commercial, heated	garden fruit	tomato sauce	0.05	0.20	0.484	0.0242	0.0048	3.1980	0.1599	0.0320	12.4450	0.6223	0.1245	39.9780	1.9989	0.3998
145	chili con carne, beef and beans, canned	garden fruit	tomato sauce	0.16	0.10	0.938	0.1501	0.0150	2.2260	0.3562	0.0356	7.8950	1.2632	0.1263	14.3070	2.2891	0.2289
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	garden fruit	tomato	0.02	0.07	0.559	0.0112	0.0008	4.5740	0.0915	0.0064	13.6950	0.2739	0.0192	18.7500	0.3750	0.0263
148	meatloaf, beef, homemade	garden fruit	tomato catsup	0.21	0.30	1.193	0.2505	0.0752	3.9830	0.8364	0.2509	6.4960	1.3642	0.4092	10.3690	2.1775	0.6532
149	spaghetti in tomato sauce, canned	garden fruit	tomato sauce	0.06	0.30	2.259	0.1355	0.0407	4.6890	0.2813	0.0844	13.2220	0.7933	0.2380	5.3900	0.3234	0.0970
150	chicken noodle casserole, homemade	garden fruit		0.06	0.10	0.288	0.0173	0.0017	1.2130	0.0728	0.0073	1.7410	0.1045	0.0104	4.1590	0.2495	0.0250
151	lasagne, homemade	garden fruit	tomato	0.03	0.06	0.261	0.0078	0.0005	1.1370	0.0341	0.0020	2.5540	0.0766	0.0046	4.4070	0.1322	0.0079

Table A1-3: Part A - Crops

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
210	high meat ham and vegetables, (st./jr.)	legume veg		0.27	0.09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
211	vegetables with beef, (st./jr.)	legume veg	peas, beans	0.40	0.09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
212	vegetables with (trukey/chicken), (st./jr.)	legume veg	peas, beans	0.40	0.09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
213	vegetables with (bacon/ham), (st./jr.)	legume veg	peas, beans	0.37	0.09	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
219	green beans, (st./jr.)	legume veg	strained	1.00	0.08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
223	peas, (st./jr.)	legume veg	strained	1.00	0.13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		legume veg-total					33.2367	7.8752		50.2608	11.7527		39.3826	8.1826		50.6034	10.8195
127	carrots, raw	root veg	pared, with crown & tip	1.00	0.12	3.7990	3.7990	0.4559	3.0230	3.0230	0.3628	3.9930	3.9930	0.4792	3.9820	3.9820	0.4778
128	onion, raw	root veg	mature, chopped	1.00	0.11	2.3740	2.3740	0.2611	3.3730	3.3730	0.3710	2.3420	2.3420	0.2576	3.6310	3.6310	0.3994
129	vegetables, mixed, canned	root veg	carrots	0.12	0.18	5.9580	0.7150	0.1287	5.6230	0.6748	0.1215	6.8150	0.8178	0.1472	6.2630	0.7516	0.1353
131	beets, canned	root veg	drained	1.00	0.11	0.8870	0.8870	0.0976	1.2010	1.2010	0.1321	1.7480	1.7480	0.1923	1.4300	1.4300	0.1573
132	radish, raw	root veg		1.00	0.05	0.2940	0.2940	0.0147	0.4220	0.4220	0.0211	0.6020	0.6020	0.0301	0.6870	0.6870	0.0344
133	onion rings, breaded & fried, frozen, commercial,heated	root veg		0.66	0.72	0.5200	0.3432	0.2471	0.9270	0.6118	0.4405	0.1450	0.0957	0.0689	0.1120	0.0739	0.0532
139	scalloped potatoes, homemade	root veg	onion	0.02	0.11	5.1640	0.1033	0.0114	7.4240	0.1485	0.0163	5.3580	0.1072	0.0118	7.6840	0.1537	0.0169
142	spaghetti with meat sauce, homemade	root veg	onion	0.01	0.14	15.5010	0.1550	0.0217	23.9170	0.2392	0.0335	8.9560	0.0896	0.0125	11.0850	0.1109	0.0155
143	beef and vegetable stew, homemade	root veg	carrot	0.16	0.12	8.0740	1.2918	0.1550	11.3150	1.8104	0.2172	10.9010	1.7442	0.2093	14.5170	2.3227	0.2787
145	chili con carne, beef and beans, canned	root veg	onions	0.12	0.15	5.3410	0.6409	0.0961	14.3690	1.7243	0.2586	4.7300	0.5676	0.0851	9.8050	1.1766	0.1765
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	root veg	onion	0.01	0.10	10.4090	0.1041	0.0104	22.2150	0.2222	0.0222	3.3800	0.0338	0.0034	6.1860	0.0619	0.0062
148	meatloaf, beef, homemade	root veg	onion	0.02	0.11	5.5950	0.1119	0.0123	12.2880	0.2458	0.0270	4.3420	0.0868	0.0096	7.0660	0.1413	0.0155
152	potpie, frozen, commercial, chicken, oven heated	root veg	carrot	0.03	0.09	1.3440	0.0403	0.0036	2.0880	0.0626	0.0056	1.4940	0.0448	0.0040	1.3920	0.0418	0.0038
208	high meat (chicken/turkey) and vegetables, (st./jr.)	root veg	carrot	0.28	0.14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
209	high meat beef and vegetables, (st./jr.)	root veg	carrot	0.29	0.14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
210	high meat ham and vegetables, (st./jr.)	root veg	carrot	0.28	0.14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
211	vegetables with beef, (st./jr.)	root veg	carrot	0.40	0.14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
212	vegetables with (trukey/chicken), (st./jr.)	root veg	carrot	0.40	0.14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
213	vegetables with (bacon/ham), (st./jr.)	root veg	carrot	0.37	0.14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
218	carrots, (st./jr.)	root veg	strained	1.00	0.08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		root veg-total					10.8595	1.5157		13.7585	2.0296		12.2724	1.5110		14.5643	1.7705
039	pork and beans, canned	garden fruit	tomato	0.40	0.06	5.5090	2.2036	0.1322	10.2340	4.0936	0.2456	4.9630	1.9852	0.1191	7.9010	3.1604	0.1896
097	avocado, raw	garden fruit		0.93	0.16	1.3110	1.2192	0.1951	1.0550	0.9812	0.1570	0.9150	0.8510	0.1362	1.2820	1.1923	0.1908
097	avocado, raw	garden fruit	avocado oil	0.07	1.00	1.3110	0.0918	0.0918	1.0550	0.0739	0.0739	0.9150	0.0641	0.0641	1.2820	0.0897	0.0897
117	tomato, raw	garden fruit		1.00	0.06	16.2440	16.2440	0.9746	17.1930	17.1930	1.0316	22.5940	22.5940	1.3556	21.8610	21.8610	1.3117
118	tomato juice, canned	garden fruit		1.00	0.06	3.6510	3.6510	0.2191	4.7850	4.7850	0.2871	5.5580	5.5580	0.3335	5.4370	5.4370	0.3262
119	tomato sauce, canned	garden fruit	only spices, no sugar added	1.00	0.11	2.4390	2.4390	0.2683	2.9180	2.9180	0.3210	1.4200	1.4200	0.1562	1.5820	1.5820	0.1740
120	tomatoes, canned	garden fruit	solids & liquids	1.00	0.06	0.8860	0.8860	0.0532	0.3730	0.3730	0.0224	1.6190	1.6190	0.0971	1.9430	1.9430	0.1166
123	cucumber, raw, pared	garden fruit		1.00	0.05	3.4220	3.4220	0.1711	2.7100	2.7100	0.1355	4.0620	4.0620	0.2031	3.5240	3.5240	0.1762
124	squash, summer, (fresh/frozen), boiled	garden fruit		1.00	0.04	2.2450	2.2450	0.0898	1.4280	1.4280	0.0571	3.8270	3.8270	0.1531	4.2500	4.2500	0.1700
125	sweet pepper, green, raw	garden fruit		1.00	0.07	0.9810	0.9810	0.0687	1.3730	1.3730	0.0961	0.8950	0.8950	0.0627	0.8030	0.8030	0.0562
126	squash, winter (Hubbard/acorn), (raw/frozen), boiled	garden fruit	all varieties, baked	1.00	0.19	0.9870	0.9870	0.1875	1.4220	1.4220	0.2702	1.9830	1.9830	0.3768	2.3330	2.3330	0.4433
142	spaghetti with meat sauce, homemade	garden fruit	tomato	0.06	0.10	15.5010	0.9301	0.0930	23.9170	1.4350	0.1435	8.9560	0.5374	0.0537	11.0850	0.6651	0.0665
144	pizza, cheese, frozen, commercial, heated	garden fruit	tomato sauce	0.05	0.20	9.2070	0.4604	0.0921	13.5180	0.6759	0.1352	2.0030	0.1002	0.0200	2.2310	0.1116	0.0223
145	chili con carne, beef and beans, canned	garden fruit	tomato sauce	0.16	0.10	5.3410	0.8546	0.0855	14.3690	2.2990	0.2299	4.7300	0.7568	0.0757	9.8050	1.5688	0.1569
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	garden fruit	tomato	0.02	0.07	10.4090	0.2082	0.0146	22.2150	0.4443	0.0311	3.3800	0.0676	0.0047	6.1860	0.1237	0.0087
148	meatloaf, beef, homemade	garden fruit	tomato catsup	0.21	0.30	5.5950	1.1750	0.3525	12.2880	2.5805	0.7741	4.3420	0.9118	0.2735	7.0660	1.4839	0.4452
149	spaghetti in tomato sauce, canned	garden fruit	tomato sauce	0.06	0.30	4.1410	0.2485	0.0745	4.2160	0.2530	0.0759	1.8750	0.1125	0.0338	3.2770	0.1966	0.0590
150	chicken noodle casserole, homemade	garden fruit		0.06	0.10	2.3550	0.1413	0.0141	5.2490	0.3149	0.0315	2.1530	0.1292	0.0129	1.7760	0.1066	0.0107
151	lasagne, homemade	garden fruit	tomato	0.03	0.06	3.0440	0.0913	0.0055	5.1430	0.1543	0.0093	1.5230	0.0457	0.0027	1.9470	0.0584	0.0033

Table A1-3: Part A - Crops

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
156	tomato soup, canned, reconstituted with whole milk	garden fruit	tomato	0.22	0.18	3.052	0.6714	0.1209	5.7570	1.2665	0.2280	6.0000	1.3200	0.2376	5.4890	1.2076	0.2174
161	pickles, dill, bottled	garden fruit	cucumber	1.00	0.07	0.004	0.0040	0.0003	0.5780	0.5780	0.0405	1.5510	1.5510	0.1086	1.2490	1.2490	0.0874
173	catsup, bottled	garden fruit		0.45	0.07	0.102	0.0459	0.0032	1.3110	0.5906	0.0413	2.3670	1.0652	0.0746	4.4720	2.0124	0.1409
186	pumpkin pie, frozen, heated	garden fruit	pumpkin	0.40	0.26	0.440	0.1760	0.0458	1.0020	0.4008	0.1042	3.0270	1.2108	0.3148	3.2390	1.2956	0.3369
215	tomatoes, beef and macaroni, (st./jr.)	garden fruit	tomato	0.27	0.10	3.958	1.0687	0.1069	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		garden fruit-total					4.9824	0.6650		15.9343	1.6690		28.8519	3.0740		37.0112	3.8632
047	peanut butter, creamy, commercial in jar	peanuts	peanut oil	0.19	0.99	0.496	0.0942	0.0933	2.9110	0.5531	0.5476	2.1700	0.4123	0.4082	4.6830	0.8898	0.8809
047	peanut butter, creamy, commercial in jar	peanuts		0.50	0.98	0.496	0.2480	0.2430	2.9110	1.4555	1.4264	2.1700	1.0850	1.0633	4.6830	2.3415	2.2947
048	peanuts, dry roasted in jar, salted	peanuts		1.00	0.98	0.000	0.0000	0.0000	0.2390	0.2390	0.2342	0.3170	0.3170	0.3107	0.8850	0.8850	0.8673
		peanuts-total					0.3422	0.3363		2.2476	2.2082		1.8143	1.7821		4.1163	4.0428
153	pork chow mein, homemade	mushroom		0.01	0.04	0.321	0.0032	0.0001	0.8090	0.0081	0.0003	2.0730	0.0207	0.0008	3.1190	0.0312	0.0012
130	mushrooms, canned	mushroom	drained	1.00	0.10	0.000	0.0000	0.0000	0.124	0.1240	0.0124	0.543	0.5430	0.0543	0.308	0.3080	0.0308
		mushroom-total					0.0032	0.0001		0.1321	0.0127		0.5637	0.0551		0.3392	0.0320
016	beef (loin/sirloin) steak, pan cooked with added fat	veg oil		0.04	1.00	0.018	0.0007	0.0007	4.0730	0.1629	0.1629	9.9370	0.3975	0.3975	16.6480	0.6659	0.6659
018	pork chop, pan cooked with added fat	veg oil		0.04	1.00	0.686	0.0274	0.0274	3.9870	0.1595	0.1595	5.5820	0.2233	0.2233	8.3300	0.3332	0.3332
022	lamb chop, pan cooked with added fat	veg oil		0.04	1.00	0.577	0.0231	0.0231	0.3180	0.0127	0.0127	0.2560	0.0102	0.0102	0.1820	0.0073	0.0073
023	veal cutlet, breaded, pan cooked with added fat	veg oil		0.10	1.00	0.000	0.0000	0.0000	0.2120	0.0212	0.0212	0.4520	0.0452	0.0452	0.3870	0.0387	0.0387
024	chicken,drumstk/breast,breaded,fried w/add.fat,homemade	veg oil		0.13	1.00	1.084	0.1409	0.1409	5.8820	0.7647	0.7647	9.4950	1.2343	1.2343	12.2340	1.5904	1.5904
027	liver (beef/calf), pan fried with added fat	veg oil		0.02	1.00	0.506	0.0101	0.0101	0.7200	0.0144	0.0144	0.8400	0.0168	0.0168	1.3250	0.0265	0.0265
032	tuna, canned in oil, drained	veg oil		0.08	1.00	0.300	0.0240	0.0240	1.4710	0.1177	0.1177	3.3560	0.2685	0.2685	2.6500	0.2120	0.2120
033	shrimp(fresh/frozen),breaded&fried w/add. fat,homemade	veg oil		0.06	1.00	0.000	0.0000	0.0000	0.1240	0.0074	0.0074	0.7600	0.0456	0.0456	1.1970	0.0718	0.0718
034	fish sticks, commercial, frozen, oven cooked	veg oil		0.11	1.00	0.259	0.0285	0.0285	1.1560	0.1272	0.1272	1.7070	0.1878	0.1878	1.7160	0.1888	0.1888
035	eggs, scrambled with added milk and fat	veg oil	margarine	0.03	1.00	6.374	0.1912	0.1912	13.0880	0.3926	0.3926	7.8550	0.2357	0.2357	12.0730	0.3622	0.3622
036	eggs, fried with added fat	veg oil		0.06	1.00	2.627	0.1576	0.1576	6.1290	0.3677	0.3677	4.5490	0.2729	0.2729	10.0200	0.6012	0.6012
057	popcorn, popped in oil	veg oil	coconut oil	0.22	1.00	0.150	0.0330	0.0330	0.6970	0.1533	0.1533	1.1870	0.2611	0.2611	1.5000	0.3300	0.3300
058	whitebread, enriched	veg oil		0.02	1.00	6.303	0.1261	0.1261	26.8370	0.5367	0.5367	38.7510	0.7750	0.7750	55.6760	1.1136	1.1136
059	rolls, white, soft, enriched	veg oil		0.05	1.00	0.770	0.0385	0.0385	4.1040	0.2052	0.2052	13.2400	0.6620	0.6620	21.4950	1.0748	1.0748
060	cornbread, southern style, homemade	veg oil		0.06	1.00	0.877	0.0526	0.0526	3.2590	0.1955	0.1955	4.4320	0.2659	0.2659	6.8760	0.4126	0.4126
061	biscuits,baking powder,enriched,refrigerated type,baked	veg oil		0.08	1.00	0.620	0.0496	0.0496	2.5820	0.2066	0.2066	3.6680	0.2934	0.2934	4.8560	0.3885	0.3885
062	whole wheat bread	veg oil		0.03	1.00	0.653	0.0196	0.0196	2.7060	0.0812	0.0812	2.1560	0.0647	0.0647	3.3770	0.1013	0.1013
064	rye bread	veg oil		0.04	1.00	0.082	0.0033	0.0033	0.3720	0.0149	0.0149	0.6860	0.0274	0.0274	0.7730	0.0309	0.0309
065	muffins (blueberry/plain)	veg oil		0.14	1.00	0.039	0.0055	0.0055	0.6870	0.0962	0.0962	0.9140	0.1280	0.1280	0.7240	0.1014	0.1014
066	saltine crackers	veg oil		0.10	1.00	2.874	0.2874	0.2874	3.3540	0.3354	0.3354	2.5210	0.2521	0.2521	3.0220	0.3022	0.3022
067	corn chips	veg oil		0.20	1.00	0.106	0.0212	0.0212	1.3760	0.2752	0.2752	2.8940	0.5788	0.5788	2.3540	0.4708	0.4708
068	pancakes made from mix w/addition of egg, milk and oil	veg oil		0.08	1.00	1.075	0.0860	0.0860	5.8330	0.4666	0.4665	5.7260	0.4581	0.4581	8.0120	0.6410	0.6410
111	coleslaw with dressing, homemade	veg oil	mayonnaise	0.08	1.00	0.001	0.0001	0.0001	0.3470	0.0278	0.0278	1.9620	0.1570	0.1570	1.9830	0.1586	0.1586
133	onion rings, breaded & fried, frozen, commercial,heated	veg oil		0.23	1.00	0.050	0.0115	0.0115	0.0970	0.0223	0.0223	0.6870	0.1580	0.1580	1.8700	0.4301	0.4301
134	French fries, frozen, commercial, heated	veg oil		0.08	1.00	2.475	0.1980	0.1980	13.5650	1.0852	1.0852	19.9540	1.5963	1.5963	31.2120	2.4970	2.4970
135	mashed potatoes w/marg. & milk, prepared from instant	veg oil		0.01	0.99	7.389	0.0739	0.0732	9.8790	0.0988	0.0978	15.0040	0.1500	0.1485	24.5260	0.2453	0.2428
138	potato chips, commercial	veg oil		0.40	1.00	0.166	0.0664	0.0664	2.0570	0.8228	0.8228	4.1910	1.6764	1.6764	6.3520	2.5408	2.5408
139	scalloped potatoes, homemade	veg oil		0.15	1.00	1.023	0.1534	0.1534	2.0490	0.3073	0.3073	4.1450	0.6217	0.6217	5.8710	0.8807	0.8807
141	sweet potato, candied, homemade	veg oil		0.14	1.00	0.095	0.0133	0.0133	0.3550	0.0497	0.0497	0.3220	0.0451	0.0451	0.9470	0.1326	0.1326
144	pizza, cheese, frozen, commercial, heated	veg oil		0.12	1.00	0.484	0.0581	0.0581	3.1980	0.3838	0.3838	12.4450	1.4934	1.4934	39.9780	4.7974	4.7974
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	veg oil		0.20	1.00	0.559	0.1118	0.1118	4.5740	0.9148	0.9148	13.6950	2.7390	2.7390	18.7500	3.7500	3.7500
150	chicken noodle casserole, homemade	veg oil		0.15	1.00	0.288	0.0432	0.0432	1.2130	0.1820	0.1820	1.7410	0.2612	0.2612	4.1590	0.6238	0.6238
152	potpie, frozen, commercial, chicken, oven heated	veg oil		0.05	1.00	0.142	0.0071	0.0071	1.7610	0.0881	0.0881	1.4120	0.0706	0.0706	2.1170	0.1059	0.1059

Table A1-3: Part A - Crops

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
156	tomato soup, canned, reconstituted with whole milk	garden fruit	tomato	0.22	0.18	10.8540	2.3879	0.4298	11.1120	2.4446	0.4400	11.7070	2.5755	0.4636	11.6200	2.5564	0.4602
161	pickles, dill, bottled	garden fruit	cucmber	1.00	0.07	1.3090	1.3090	0.0916	1.7280	1.7280	0.1210	1.0060	1.0060	0.0704	1.1020	1.1020	0.0771
173	catsup, bottled	garden fruit		0.45	0.07	1.6620	0.7479	0.0524	4.2630	1.9184	0.1343	0.7940	0.3573	0.0250	0.8150	0.3667	0.0257
186	pumpkin pie, frozen, heated	garden fruit	pumpkin	0.40	0.26	3.3030	1.3212	0.3435	5.5980	2.2392	0.5822	4.8070	1.9228	0.4999	5.2000	2.0800	0.5408
215	tomatoes, beef and macaroni, (st./jr.)	garden fruit	tomato	0.27	0.10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		garden fruit-total					44.2448	4.1004		53.8377	5.4053		53.3809	4.5935		56.5952	5.1207
047	peanut butter, creamy, commercial in jar	peanuts	peanut oil	0.19	0.99	1.2140	0.2307	0.2284	2.5290	0.4805	0.4757	1.1940	0.2269	0.2246	1.8230	0.3464	0.3429
047	peanut butter, creamy, commercial in jar	peanuts		0.50	0.98	1.2140	0.6070	0.5949	2.5290	1.2645	1.2392	1.1940	0.5970	0.5851	1.8230	0.9115	0.8933
048	peanuts, dry roasted in jar, salted	peanuts		1.00	0.98	0.7310	0.7310	0.7164	1.6330	1.6330	1.6003	0.5410	0.5410	0.5302	1.2690	1.2690	1.2436
		peanuts-total					1.5687	1.5396		3.3780	3.3153		1.3649	1.3398		2.5269	2.4798
153	pork chow mein, homemade	mushroom		0.01	0.04	3.8240	0.0382	0.0015	4.5130	0.0451	0.0018	2.9200	0.0292	0.0012	2.9040	0.0290	0.0012
130	mushrooms, canned	mushroom	drained	1.00	0.10	1.359	1.3590	0.1359	1.337	1.3370	0.1337	0.496	0.4960	0.0496	0.693	0.6930	0.0693
		mushroom-total					1.3972	0.1374		1.3821	0.1355		0.5252	0.0508		0.7220	0.0705
016	beef (loin/sirloin) steak, pan cooked with added fat	veg oil		0.04	1.00	15.4270	0.6171	0.6171	49.4760	1.9790	1.9790	11.9700	0.4788	0.4788	21.7690	0.8708	0.8708
018	pork chop, pan cooked with added fat	veg oil		0.04	1.00	5.8580	0.2343	0.2343	11.8260	0.4730	0.4730	4.5540	0.1822	0.1822	7.6250	0.3050	0.3050
022	lamb chop, pan cooked with added fat	veg oil		0.04	1.00	1.3740	0.0550	0.0550	1.0770	0.0431	0.0431	0.8740	0.0350	0.0350	0.8840	0.0354	0.0354
023	veal cutlet, breaded, pan cooked with added fat	veg oil		0.10	1.00	1.3450	0.1345	0.1345	0.8390	0.0839	0.0839	0.9510	0.0951	0.0951	1.3510	0.1351	0.1351
024	chicken,drumstk/breast,breaded,fried w/add.fat,homemade	veg oil		0.13	1.00	8.9940	1.1692	1.1692	12.4750	1.6218	1.6218	7.3440	0.9547	0.9547	9.2560	1.2033	1.2033
027	liver (beef/calf), pan fried with added fat	veg oil		0.02	1.00	3.7380	0.0748	0.0748	2.7980	0.0560	0.0560	2.9270	0.0585	0.0585	4.3810	0.0876	0.0876
032	tuna, canned in oil, drained	veg oil		0.08	1.00	4.2530	0.3402	0.3402	4.4570	0.3566	0.3566	3.7310	0.2985	0.2985	3.1100	0.2488	0.2488
033	shrimp(fresh/frozen),breaded&fried w/add. fat,homemade	veg oil		0.06	1.00	2.6550	0.1593	0.1593	3.4720	0.2083	0.2083	1.9740	0.1184	0.1184	1.8440	0.1106	0.1106
034	fish sticks, commercial, frozen, oven cooked	veg oil		0.11	1.00	1.7420	0.1916	0.1916	2.1410	0.2355	0.2355	1.0890	0.1198	0.1198	1.0530	0.1158	0.1158
035	eggs, scrambled with added milk and fat	veg oil	margarine	0.03	1.00	9.7830	0.2935	0.2935	15.0470	0.4514	0.4514	10.0850	0.3026	0.3026	12.5790	0.3774	0.3774
036	eggs, fried with added fat	veg oil		0.06	1.00	6.0360	0.3622	0.3622	11.4990	0.6899	0.6899	6.5660	0.3940	0.3940	16.5100	0.9906	0.9906
057	popcorn, popped in oil	veg oil	coconut oil	0.22	1.00	1.6900	0.3718	0.3718	1.4320	0.3150	0.3150	0.1250	0.0275	0.0275	0.2530	0.0557	0.0557
058	whitebread, enriched	veg oil		0.02	1.00	34.4240	0.6885	0.6885	36.7200	0.7344	0.7344	34.9880	0.6998	0.6998	50.8730	1.0175	1.0175
059	rolls, white, soft, enriched	veg oil		0.05	1.00	10.0550	0.5028	0.5028	20.2870	1.0144	1.0144	6.0290	0.3015	0.3015	9.0500	0.4525	0.4525
060	cornbread, southern style, homemade	veg oil		0.06	1.00	3.8690	0.2321	0.2321	8.8500	0.5310	0.5310	8.3130	0.4988	0.4988	11.9270	0.7156	0.7156
061	biscuits,baking powder,enriched,refrigerated type,baked	veg oil		0.08	1.00	3.0630	0.2450	0.2450	5.0310	0.4025	0.4025	4.0800	0.3264	0.3264	7.8060	0.6245	0.6245
062	whole wheat bread	veg oil		0.03	1.00	4.1780	0.1253	0.1253	7.7820	0.2335	0.2335	5.4900	0.1647	0.1647	6.5870	0.1976	0.1976
064	rye bread	veg oil		0.04	1.00	1.7110	0.0684	0.0684	2.6660	0.1066	0.1066	3.1830	0.1273	0.1273	3.6830	0.1473	0.1473
065	muffins (blueberry/plain)	veg oil		0.14	1.00	0.9470	0.1326	0.1326	0.9450	0.1323	0.1323	1.0140	0.1420	0.1420	0.8380	0.1173	0.1173
066	saltine crackers	veg oil		0.10	1.00	3.4820	0.3482	0.3482	3.9120	0.3912	0.3912	3.5590	0.3559	0.3559	4.0590	0.4059	0.4059
067	corn chips	veg oil		0.20	1.00	0.8090	0.1618	0.1618	2.3580	0.4716	0.4716	0.2080	0.0416	0.0416	0.5100	0.1020	0.1020
068	pancakes made from mix w/addition of egg, milk and oil	veg oil		0.08	1.00	4.4820	0.3586	0.3586	6.9760	0.5581	0.5581	3.6180	0.2894	0.2894	6.2960	0.5037	0.5037
111	coleslaw with dressing, homemade	veg oil	mayonnaise	0.08	1.00	2.4220	0.1938	0.1938	2.8870	0.2310	0.2310	2.6740	0.2139	0.2139	3.2530	0.2602	0.2602
133	onion rings, breaded & fried, frozen, commercial,heated	veg oil		0.23	1.00	0.5200	0.1196	0.1196	0.9270	0.2132	0.2132	0.1450	0.0334	0.0334	0.1120	0.0258	0.0258
134	French fries, frozen, commercial, heated	veg oil		0.08	1.00	15.7010	1.2561	1.2561	32.7500	2.6200	2.6200	6.0180	0.4814	0.4814	14.5180	1.1614	1.1614
135	mashed potatoes w/marg. & milk, prepared from instant	veg oil		0.01	0.99	11.6100	0.1161	0.1149	18.8350	0.1884	0.1865	10.4050	0.1040	0.1030	17.0150	0.1702	0.1684
138	potato chips, commercial	veg oil		0.40	1.00	2.1940	0.8776	0.8776	4.0370	1.6148	1.6148	0.4490	0.1796	0.1796	0.5530	0.2212	0.2212
139	scalloped potatoes, homemade	veg oil		0.15	1.00	5.1640	0.7746	0.7746	7.4240	1.1136	1.1136	5.3580	0.8037	0.8037	7.6840	1.1526	1.1526
141	sweet potato, candied, homemade	veg oil		0.14	1.00	0.5620	0.0787	0.0787	1.0080	0.1411	0.1411	0.6090	0.0853	0.0853	0.5930	0.0830	0.0830
144	pizza, cheese, frozen, commercial, heated	veg oil		0.12	1.00	9.2070	1.1048	1.1048	13.5180	1.6222	1.6222	2.0030	0.2404	0.2404	2.2310	0.2677	0.2677
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	veg oil		0.20	1.00	10.4090	2.0818	2.0818	22.2150	4.4430	4.4430	3.3800	0.6760	0.6760	6.1860	1.2372	1.2372
150	chicken noodle casserole, homemade	veg oil		0.15	1.00	2.3550	0.3533	0.3533	5.2490	0.7873	0.7873	2.1530	0.3230	0.3230	1.7760	0.2664	0.2664
152	potpie, frozen, commercial, chicken, oven heated	veg oil		0.05	1.00	1.3440	0.0672	0.0672	2.0880	0.1044	0.1044	1.4940	0.0747	0.0747	1.3920	0.0696	0.0696

Table A1-3: Part A - Crops

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
153	pork chow mein, homemade	veg oil		0.04	1.00	0.321	0.0128	0.0128	0.8090	0.0324	0.0324	2.0730	0.0829	0.0829	3.1190	0.1248	0.1248
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	veg oil		0.07	1.00	0.065	0.0046	0.0046	1.6920	0.1184	0.1184	1.3290	0.0930	0.0930	0.8830	0.0618	0.0618
155	chicken noodle soup, canned, reconstituted with water	veg oil		0.01	1.00	6.835	0.0684	0.0684	17.8080	0.1781	0.1781	12.6120	0.1261	0.1261	7.0820	0.0708	0.0708
156	tomato soup, canned, reconstituted with whole milk	veg oil		0.11	1.00	3.052	0.3357	0.3357	5.7570	0.6333	0.6333	6.0000	0.6600	0.6600	5.4890	0.6038	0.6038
162	margarine made w/partially hydrog. veg. oil,stick type	veg oil		1.00	0.84	0.888	0.8880	0.7459	2.6900	2.6900	2.2596	2.7650	2.7650	2.3226	4.7190	4.7190	3.9640
163	salad dressing, italian, bottled	veg oil	regular	1.00	0.72	0.055	0.0550	0.0396	0.9380	0.9380	0.6754	3.1320	3.1320	2.2550	3.1910	3.1910	2.2975
165	vegetable oil, corn, bottled	veg oil		1.00	1.00	0.167	0.1670	0.1670	0.5450	0.5450	0.5450	0.8030	0.8030	0.8030	1.0200	1.0200	1.0200
166	mayonnaise, bottled	veg oil		0.40	1.00	0.046	0.0184	0.0184	0.4980	0.1992	0.1992	1.3850	0.5540	0.5540	1.4240	0.5696	0.5696
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	veg oil		0.17	1.00	0.170	0.0289	0.0289	2.3260	0.3954	0.3954	6.7310	1.1443	1.1443	8.5340	1.4508	1.4508
179	yellow cake prep. from mix w/white icing prep. from mix	veg oil		0.17	1.00	0.634	0.1078	0.1078	3.1700	0.5389	0.5389	8.4330	1.4336	1.4336	12.1270	2.0616	2.0616
180	coffeecake, (ready-to-eat/frozen)	veg oil		0.20	1.00	0.052	0.0104	0.0104	0.2910	0.0582	0.0582	1.2450	0.2490	0.2490	0.9190	0.1838	0.1838
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	veg oil		0.20	1.00	0.516	0.1032	0.1032	2.3650	0.4730	0.4730	4.0180	0.8036	0.8036	6.6590	1.3318	1.3318
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	veg oil	margarine	0.20	1.00	0.119	0.0238	0.0238	0.5470	0.1094	0.1094	2.0850	0.4170	0.4170	5.1720	1.0344	1.0344
183	cookies, chocolate chip	veg oil		0.13	1.00	2.604	0.3385	0.3385	7.6350	0.9926	0.9926	5.9690	0.7760	0.7760	8.0760	1.0499	1.0499
184	cookies, sandwich type, chocolate w/white cream filling	veg oil		0.10	1.00	0.844	0.0844	0.0844	3.1210	0.3121	0.3121	1.7950	0.1795	0.1795	3.9590	0.3959	0.3959
185	apple pie, frozen, heated	veg oil		0.18	1.00	0.224	0.0403	0.0403	1.6930	0.3047	0.3047	5.9050	1.0629	1.0629	8.3570	1.5043	1.5043
186	pumpkin pie, frozen, heated	veg oil		0.09	1.00	0.440	0.0396	0.0396	1.0020	0.0902	0.0902	3.0270	0.2724	0.2724	3.2390	0.2915	0.2915
187	candy, plain milk chocolate	veg oil		0.23	1.00	0.220	0.0506	0.0506	2.6510	0.6097	0.6097	5.7000	1.3110	1.3110	5.7880	1.3312	1.3312
202	milk-based infant formula w/iron,canned,ready-to serve	veg oil		0.18	1.00	47.728	8.5910	8.5910	0.6820	0.1228	0.1228	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
203	milk-based infant formula w/o iron,canned,ready-to-serv	veg oil		0.18	1.00	81.931	14.7476	14.7476	1.9000	0.3420	0.3420	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		veg oil-total					27.7791	27.6209		18.3807	17.6867		31.5384	30.2176		46.2229	44.5719

Table A1-3: Part A - Crops

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
153	pork chow mein, homemade	veg oil		0.04	1.00	3.8240	0.1530	0.1530	4.5130	0.1805	0.1805	2.9200	0.1168	0.1168	2.9040	0.1162	0.1162
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	veg oil		0.07	1.00	1.3990	0.0979	0.0979	1.2230	0.0856	0.0856	1.2620	0.0883	0.0883	1.9460	0.1362	0.1362
155	chicken noodle soup, canned, reconstituted with water	veg oil		0.01	1.00	7.0920	0.0709	0.0709	7.5110	0.0751	0.0751	8.2750	0.0828	0.0828	14.2020	0.1420	0.1420
156	tomato soup, canned, reconstituted with whole milk	veg oil		0.11	1.00	10.8540	1.1939	1.1939	11.1120	1.2223	1.2223	11.7070	1.2878	1.2878	11.6200	1.2782	1.2782
162	margarine made w/partially hydrog. veg. oil,stick type	veg oil		1.00	0.84	3.6910	3.6910	3.1004	4.6470	4.6470	3.9035	4.5750	4.5750	3.8430	5.6810	5.6810	4.7720
163	salad dressing, italian, bottled	veg oil	regular	1.00	0.72	5.5880	5.5880	4.0234	5.7450	5.7450	4.1364	3.4340	3.4340	2.4725	3.8480	3.8480	2.7706
165	vegetable oil, corn, bottled	veg oil		1.00	1.00	1.3620	1.3620	1.3620	1.5090	1.5090	1.5090	0.9000	0.9000	0.9000	1.2140	1.2140	1.2140
166	mayonnaise, bottled	veg oil		0.40	1.00	1.3140	0.5256	0.5256	2.7290	1.0916	1.0916	1.1110	0.4444	0.4444	1.5550	0.6220	0.6220
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	veg oil		0.17	1.00	3.3420	0.5681	0.5681	5.9130	1.0052	1.0052	1.9840	0.3373	0.3373	3.4690	0.5897	0.5897
179	yellow cake prep. from mix w/white icing prep. from mix	veg oil		0.17	1.00	5.5890	0.9501	0.9501	8.9790	1.5264	1.5264	6.8930	1.1718	1.1718	8.2560	1.4035	1.4035
180	coffeecake, (ready-to-eat/frozen)	veg oil		0.20	1.00	0.7440	0.1488	0.1488	1.3960	0.2792	0.2792	1.1990	0.2398	0.2398	1.4900	0.2980	0.2980
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	veg oil		0.20	1.00	3.6910	0.7382	0.7382	5.6830	1.1366	1.1366	2.3070	0.4614	0.4614	4.7270	0.9454	0.9454
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	veg oil	margarine	0.20	1.00	2.0300	0.4060	0.4060	3.6500	0.7300	0.7300	2.5210	0.5042	0.5042	3.1590	0.6318	0.6318
183	cookies, chocolate chip	veg oil		0.13	1.00	3.7510	0.4876	0.4876	4.7230	0.6140	0.6140	3.0840	0.4009	0.4009	4.5760	0.5949	0.5949
184	cookies, sandwich type, chocolate w/white cream filling	veg oil		0.10	1.00	1.6480	0.1648	0.1648	2.7150	0.2715	0.2715	1.0520	0.1052	0.1052	2.4320	0.2432	0.2432
185	apple pie, frozen, heated	veg oil		0.18	1.00	4.8960	0.8813	0.8813	7.3590	1.3246	1.3246	6.2820	1.1308	1.1308	8.7150	1.5687	1.5687
186	pumpkin pie, frozen, heated	veg oil		0.09	1.00	3.3030	0.2973	0.2973	5.5980	0.5038	0.5038	4.8070	0.4326	0.4326	5.2000	0.4680	0.4680
187	candy, plain milk chocolate	veg oil		0.23	1.00	2.7970	0.6433	0.6433	4.0900	0.9407	0.9407	1.9950	0.4589	0.4589	1.9000	0.4370	0.4370
202	milk-based infant formula w/iron,canned,ready-to serve	veg oil		0.18	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
203	milk-based infant formula w/o iron,canned,ready-to-serv	veg oil		0.18	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		veg oil-total					31.8582	29.7018		47.0562	44.7022		25.3996	23.7050		33.9531	31.9630

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
013	beef, ground, regular hamburger, cooked in patty shape	beef		0.80	0.46	2.282	1.8256	0.8398	10.9730	8.7784	4.0381	19.6930	15.7544	7.2470	32.5150	26.0120	11.9655
014	beef chuck roast, oven roasted	beef		0.85	0.38	0.613	0.5211	0.1980	4.7540	4.0409	1.5355	9.2260	7.8421	2.9800	15.2900	12.9965	4.9387
015	beef, round steak, stewed in water	beef		0.85	0.39	0.953	0.8100	0.3159	0.5490	0.4667	0.1820	1.2100	1.0285	0.4011	1.7010	1.4459	0.5639
016	beef (loin/sirloin) steak, pan cooked with added fat	beef		0.70	0.26	0.018	0.0126	0.0033	4.0730	2.8511	0.7413	9.9370	6.9559	1.8085	16.6480	11.6536	3.0299
023	veal cutlet, breaded, pan cooked with added fat	beef		0.42	0.15	0.000	0.0000	0.0000	0.2120	0.0890	0.0134	0.4520	0.1898	0.0285	0.3870	0.1625	0.0244
028	frankfurters, (beef/beef and pork), boiled	beef	assume beef	0.71	0.18	2.104	1.4938	0.2689	8.5830	6.0939	1.0969	6.4370	4.5703	0.8226	8.7610	6.2203	1.1197
142	spaghetti with meat sauce, homemade	beef		0.07	0.26	4.786	0.3350	0.0871	16.4100	1.1487	0.2987	17.4770	1.2234	0.3181	33.5700	2.3499	0.6110
143	beef and vegetable stew, homemade	beef		0.45	0.33	2.838	1.2771	0.4214	5.7980	2.6091	0.8610	8.8880	3.9996	1.3199	10.8960	4.9032	1.6181
145	chili con carne, beef and beans, canned	beef		0.34	0.12	0.938	0.3189	0.0383	2.2260	0.7568	0.0908	7.8950	2.6843	0.3221	14.3070	4.8644	0.5837
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	beef		0.32	0.12	0.559	0.1789	0.0215	4.5740	1.4637	0.1756	13.6950	4.3824	0.5259	18.7500	6.0000	0.7200
148	meatloaf, beef, homemade	beef		0.40	0.26	1.193	0.4772	0.1241	3.9830	1.5932	0.4142	6.4960	2.5984	0.6756	10.3690	4.1476	1.0784
151	lasagne, homemade	beef		0.14	0.30	0.261	0.0365	0.0110	1.1370	0.1592	0.0478	2.5540	0.3576	0.1073	4.4070	0.6170	0.1851
157	vegetable beef soup, canned, reconstituted with water	beef		0.02	0.10	5.792	0.1158	0.0116	16.1960	0.3239	0.0324	12.1130	0.2423	0.0242	13.2320	0.2646	0.0265
158	beef bouillon, canned, reconstituted with water	beef		0.74	0.14	0.274	0.2028	0.0284	1.0490	0.7763	0.1087	0.7770	0.5750	0.0805	1.1820	0.8747	0.1225
205	beef, (st./jr.)	beef	strained	0.96	0.16	6.294	6.0422	0.9668	0.0890	0.0854	0.0137	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
209	high meat beef and vegetables, (st./jr.)	beef	strained	0.39	0.13	9.236	3.6020	0.4683	0.2070	0.0807	0.0105	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
211	vegetables with beef, (st./jr.)	beef	strained	0.18	0.06	12.717	2.2891	0.1373	0.1470	0.0265	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
215	tomatoes, beef and macaroni, (st./jr.)	beef	strained	0.08	0.15	3.958	0.3166	0.0475	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		beef-total					19.8554	3.9890		31.3435	9.6621		52.4039	16.6613		82.5122	26.5872
013	beef, ground, regular hamburger, cooked in patty shape	beef fat		0.20	1.00	2.282	0.4564	0.4564	10.9730	2.1946	2.1946	19.6930	3.9386	3.9386	32.5150	6.5030	6.5030
014	beef chuck roast, oven roasted	beef fat		0.15	1.00	0.613	0.0919	0.0919	4.7540	0.7131	0.7131	9.2260	1.3839	1.3839	15.2900	2.2935	2.2935
015	beef, round steak, stewed in water	beef fat		0.15	1.00	0.953	0.1430	0.1430	0.5490	0.0824	0.0824	1.2100	0.1815	0.1815	1.7010	0.2552	0.2552
016	beef (loin/sirloin) steak, pan cooked with added fat	beef fat	assume not trimmed	0.26	1.00	0.018	0.0047	0.0047	4.0730	1.0590	1.0590	9.9370	2.5836	2.5836	16.6480	4.3285	4.3285
023	veal cutlet, breaded, pan cooked with added fat	beef fat		0.08	1.00	0.000	0.0000	0.0000	0.2120	0.0170	0.0170	0.4520	0.0362	0.0362	0.3870	0.0310	0.0310
142	spaghetti with meat sauce, homemade	beef fat		0.02	1.00	4.786	0.0957	0.0957	16.4100	0.3282	0.3282	17.4770	0.3495	0.3495	33.5700	0.6714	0.6714
143	beef and vegetable stew, homemade	beef fat		0.14	1.00	2.838	0.3973	0.3973	5.7980	0.8117	0.8117	8.8880	1.2443	1.2443	10.8960	1.5254	1.5254
145	chili con carne, beef and beans, canned	beef fat		0.05	1.00	0.938	0.0469	0.0469	2.2260	0.1113	0.1113	7.8950	0.3948	0.3948	14.3070	0.7154	0.7154
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	beef fat		0.10	1.00	0.559	0.0559	0.0559	4.5740	0.4574	0.4574	13.6950	1.3695	1.3695	18.7500	1.8750	1.8750
148	meatloaf, beef, homemade	beef fat		0.13	1.00	1.193	0.1551	0.1551	3.9830	0.5178	0.5178	6.4960	0.8445	0.8445	10.3690	1.3480	1.3480
151	lasagne, homemade	beef fat		0.05	1.00	0.261	0.0131	0.0131	1.1370	0.0569	0.0569	2.5540	0.1277	0.1277	4.4070	0.2204	0.2204
158	beef bouillon, canned, reconstituted with water	beef fat		0.11	1.00	0.274	0.0301	0.0301	1.0490	0.1154	0.1154	0.7770	0.0855	0.0855	1.1820	0.1300	0.1300
205	beef, (st./jr.)	beef fat		0.04	1.00	6.294	0.2518	0.2518	0.0890	0.0036	0.0036	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
209	high meat beef and vegetables, (st./jr.)	beef fat		0.04	1.00	9.236	0.3694	0.3694	0.2070	0.0083	0.0083	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
211	vegetables with beef, (st./jr.)	beef fat		0.02	1.00	12.717	0.2543	0.2543	0.1470	0.0029	0.0029	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
215	tomatoes, beef and macaroni, (st./jr.)	beef fat		0.02	1.00	3.958	0.0792	0.0792	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		beef fat-total					2.4448	2.4448		6.4794	6.4794		12.5395	12.5395		19.8966	19.8966
027	liver (beef/calf), pan fried with added fat	beef liver		0.89	0.37	0.506	0.4503	0.1666	0.7290	0.6488	0.2401	0.8400	0.7476	0.2766	1.3250	1.1793	0.4363
		beef liver-total					0.4503	0.1666		0.6488	0.2401		0.7476	0.2766		1.1793	0.4363
027	liver (beef/calf), pan fried with added fat	beef liver fat		0.09	1.00	0.506	0.0455	0.0455	0.7290	0.0656	0.0656	0.8400	0.0756	0.0756	1.3250	0.1193	0.1193
		beef liver fat-total					0.0455	0.0455		0.0656	0.0656		0.0756	0.0756		0.1193	0.1193
022	lamb chop, pan cooked with added fat	lamb		0.71	0.34	0.577	0.4097	0.1393	0.3180	0.2258	0.0768	0.2560	0.1818	0.0618	0.1820	0.1292	0.0439
		lamb-total					0.4097	0.1393		0.2258	0.0768		0.1818	0.0618		0.1292	0.0439
022	lamb chop, pan cooked with added fat	lamb fat	assume not trimmed	0.25	1.00	0.577	0.1443	0.1443	0.3180	0.0795	0.0795	0.2560	0.0640	0.0640	0.1820	0.0455	0.0455
		lamb fat-total					0.1443	0.1443		0.0795	0.0795		0.0640	0.0640		0.0455	0.0455

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
013	beef, ground, regular hamburger, cooked in patty shape	beef		0.80	0.46	16.6090	13.2872	6.1121	18.0980	14.4784	6.6601	12.2110	9.7688	4.4936	17.4810	13.9848	6.4330
014	beef chuck roast, oven roasted	beef		0.85	0.38	11.0040	9.3534	3.5543	18.8450	16.0183	6.0869	10.8350	9.2098	3.4997	19.9730	16.9771	6.4513
015	beef, round steak, stewed in water	beef		0.85	0.39	1.4870	1.2640	0.4929	2.6880	2.2848	0.8911	1.0850	0.9222	0.3597	1.9950	1.6958	0.6613
016	beef (loin/sirloin) steak, pan cooked with added fat	beef		0.70	0.26	15.4270	10.7989	2.8077	49.4760	34.6332	9.0046	11.9700	8.3790	2.1785	21.7690	15.2383	3.9620
023	veal cutlet, breaded, pan cooked with added fat	beef		0.42	0.15	1.3450	0.5649	0.0847	0.8390	0.3524	0.0529	0.9510	0.3994	0.0599	1.3510	0.5674	0.0851
028	frankfurters, (beef/beef and pork), boiled	beef	assume beef	0.71	0.18	5.2320	3.7147	0.6686	8.5910	6.0996	1.0979	3.7530	2.6646	0.4796	5.3520	3.7999	0.6840
142	spaghetti with meat sauce, homemade	beef		0.07	0.26	15.5010	1.0851	0.2821	23.9170	1.6742	0.4353	8.9560	0.6269	0.1630	11.0850	0.7760	0.2017
143	beef and vegetable stew, homemade	beef		0.45	0.33	8.0740	3.6333	1.1990	11.3150	5.0918	1.6803	10.9010	4.9055	1.6188	14.5170	6.5327	2.1558
145	chili con carne, beef and beans, canned	beef		0.34	0.12	5.3410	1.8159	0.2179	14.3690	4.8855	0.5863	4.7300	1.6082	0.1930	9.8050	3.3337	0.4000
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	beef		0.32	0.12	10.4090	3.3309	0.3997	22.2150	7.1088	0.8531	3.3800	1.0816	0.1298	6.1860	1.9795	0.2375
148	meatloaf, beef, homemade	beef		0.40	0.26	5.5950	2.2380	0.5819	12.2880	4.9152	1.2780	4.3420	1.7368	0.4516	7.0660	2.8264	0.7349
151	lasagne, homemade	beef		0.14	0.30	3.0440	0.4262	0.1278	5.1430	0.7200	0.2160	1.5230	0.2132	0.0640	1.9470	0.2726	0.0819
157	vegetable beef soup, canned, reconstituted with water	beef		0.02	0.10	5.8700	0.1174	0.0117	15.0990	0.3020	0.0302	21.8390	0.4368	0.0437	20.5360	0.4107	0.0411
158	beef bouillon, canned, reconstituted with water	beef		0.74	0.14	8.0130	5.9296	0.8301	3.1020	2.2955	0.3214	3.7540	2.7780	0.3889	4.1780	3.0917	0.4328
205	beef, (st./jr.)	beef	strained	0.96	0.16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
209	high meat beef and vegetables, (st./jr.)	beef	strained	0.39	0.13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
211	vegetables with beef, (st./jr.)	beef	strained	0.18	0.06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
215	tomatoes, beef and macaroni, (st./jr.)	beef	strained	0.08	0.15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		beef-total					57.5594	17.3708		100.8595	29.1939		44.7308	14.1238		71.4865	22.5623
013	beef, ground, regular hamburger, cooked in patty shape	beef fat		0.20	1.00	16.6090	3.3218	3.3218	18.0980	3.6196	3.6196	12.2110	2.4422	2.4422	17.4810	3.4962	3.4962
014	beef chuck roast, oven roasted	beef fat		0.15	1.00	11.0040	1.6506	1.6506	18.8450	2.8267	2.8267	10.8350	1.6253	1.6253	19.9730	2.9959	2.9959
015	beef, round steak, stewed in water	beef fat		0.15	1.00	1.4870	0.2231	0.2231	2.6880	0.4032	0.4032	1.0850	0.1627	0.1627	1.9950	0.2993	0.2993
016	beef (loin/sirloin) steak, pan cooked with added fat	beef fat	assume not trimmed	0.26	1.00	15.4270	4.0110	4.0110	49.4760	12.8638	12.8638	11.9700	3.1122	3.1122	21.7690	5.6599	5.6599
023	veal cutlet, breaded, pan cooked with added fat	beef fat		0.08	1.00	1.3450	0.1076	0.1076	0.8390	0.0671	0.0671	0.9510	0.0761	0.0761	1.3510	0.1081	0.1081
142	spaghetti with meat sauce, homemade	beef fat		0.02	1.00	15.5010	0.3100	0.3100	23.9170	0.4783	0.4783	8.9560	0.1791	0.1791	11.0850	0.2217	0.2217
143	beef and vegetable stew, homemade	beef fat		0.14	1.00	8.0740	1.1304	1.1304	11.3150	1.5841	1.5841	10.9010	1.5261	1.5261	14.5170	2.0324	2.0324
145	chili con carne, beef and beans, canned	beef fat		0.05	1.00	5.3410	0.2671	0.2671	14.3690	0.7185	0.7185	4.7300	0.2365	0.2365	9.8050	0.4903	0.4903
147	1/4 lb. hamburger, white roll w/garnish, fast-food type	beef fat		0.10	1.00	10.4090	1.0409	1.0409	22.2150	2.2215	2.2215	3.3800	0.3380	0.3380	6.1860	0.6186	0.6186
148	meatloaf, beef, homemade	beef fat		0.13	1.00	5.5950	0.7273	0.7273	12.2880	1.5974	1.5974	4.3420	0.5645	0.5645	7.0660	0.9186	0.9186
151	lasagne, homemade	beef fat		0.05	1.00	3.0440	0.1522	0.1522	5.1430	0.2572	0.2572	1.5230	0.0762	0.0762	1.9470	0.0974	0.0974
158	beef bouillon, canned, reconstituted with water	beef fat		0.11	1.00	8.0130	0.8814	0.8814	3.1020	0.3412	0.3412	3.7540	0.4129	0.4129	4.1780	0.4596	0.4596
205	beef, (st./jr.)	beef fat		0.04	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
209	high meat beef and vegetables, (st./jr.)	beef fat		0.04	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
211	vegetables with beef, (st./jr.)	beef fat		0.02	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
215	tomatoes, beef and macaroni, (st./jr.)	beef fat		0.02	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		beef fat-total					13.8234	13.8234		26.9786	26.9786		10.7518	10.7518		17.3979	17.3979
027	liver (beef/calf), pan fried with added fat	beef liver		0.89	0.37	3.7380	3.3268	1.2309	2.7980	2.4902	0.9214	2.9270	2.6050	0.9639	4.3810	3.8991	1.4427
		beef liver-total					3.3268	1.2309		2.4902	0.9214		2.6050	0.9639		3.8991	1.4427
027	liver (beef/calf), pan fried with added fat	beef liver fat		0.09	1.00	3.7380	0.3364	0.3364	2.7980	0.2518	0.2518	2.9270	0.2634	0.2634	4.3810	0.3943	0.3943
		beef liver fat-total					0.3364	0.3364		0.2518	0.2518		0.2634	0.2634		0.3943	0.3943
022	lamb chop, pan cooked with added fat	lamb		0.71	0.34	1.3740	0.9755	0.3317	1.0770	0.7647	0.2600	0.8740	0.6205	0.2110	0.8840	0.6276	0.2134
		lamb-total					0.9755	0.3317		0.7647	0.2600		0.6205	0.2110		0.6276	0.2134
022	lamb chop, pan cooked with added fat	lamb fat	assume not trimmed	0.25	1.00	1.3740	0.3435	0.3435	1.0770	0.2693	0.2693	0.8740	0.2185	0.2185	0.8840	0.2210	0.2210
		lamb fat-total					0.3435	0.3435		0.2693	0.2693		0.2185	0.2185		0.2210	0.2210

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
017	pork, ham, cured, not canned, oven cooked	pork		0.78	0.46	0.302	0.2356	0.1084	2.7850	2.1723	0.9993	7.2770	5.6761	2.6110	9.8090	7.6510	3.5195
018	pork chop, pan cooked with added fat	pork		0.70	0.35	0.686	0.4802	0.1681	3.9870	2.7909	0.9768	5.5820	3.9074	1.3676	8.3300	5.8310	2.0409
019	pork sausage, (link/bulk), oven cooked	pork		0.54	0.35	0.578	0.3121	0.1092	2.2320	1.2053	0.4218	2.1400	1.1556	0.4045	4.2430	2.2912	0.8019
020	pork, bacon, oven cooked	pork		0.47	0.77	0.220	0.1034	0.0796	1.6750	0.7873	0.6062	1.7060	0.8018	0.6174	3.0850	1.4499	1.1165
021	pork roast, loin, oven cooked	pork		0.68	0.47	0.292	0.1986	0.0933	1.5990	1.0873	0.5110	4.3750	2.9750	1.3983	3.5320	2.4018	1.1288
029	bologna	pork		0.71	0.16	0.996	0.7072	0.1131	5.2430	3.7225	0.5956	5.7240	4.0640	0.6502	11.1250	7.8988	1.2638
030	salami, lunch meat type, regular, not hard	pork		0.75	0.26	0.017	0.0128	0.0033	0.4420	0.3315	0.0862	1.0060	0.7545	0.1962	0.8520	0.6390	0.1661
039	pork and beans, canned	pork		0.06	0.15	1.024	0.0614	0.0092	4.5930	0.2756	0.0413	5.5360	0.3322	0.0498	11.1670	0.6700	0.1005
153	pork chow mein, homemade	pork		0.23	0.24	0.321	0.0738	0.0177	0.8090	0.1861	0.0447	2.0730	0.4768	0.1144	3.1190	0.7174	0.1722
206	pork, (st./jr.)	pork	strained	0.94	0.18	1.489	1.3997	0.2519	0.0300	0.0282	0.0051	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
210	high meat ham and vegetables, (st./jr.)	pork	strained	0.41	0.14	3.303	1.3542	0.1896	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
213	vegetables with (bacon/ham), (st./jr.)	pork		0.24	0.10	8.112	1.9469	0.1947	0.1140	0.0274	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		pork -total					6.8858	1.3382		12.6143	4.2907		20.1434	7.4094		29.5501	10.3101
017	pork, ham, cured, not canned, oven cooked	pork fat		0.22	1.00	0.302	0.0664	0.0664	2.7850	0.6127	0.6127	7.2770	1.6009	1.6009	9.8090	2.1580	2.1580
018	pork chop, pan cooked with added fat	pork fat	assumd not trimmed	0.26	1.00	0.686	0.1784	0.1784	3.9870	1.0366	1.0366	5.5820	1.4513	1.4513	8.3300	2.1658	2.1658
019	pork sausage, (link/bulk), oven cooked	pork fat		0.46	1.00	0.578	0.2659	0.2659	2.2320	1.0267	1.0267	2.1400	0.9844	0.9844	4.2430	1.9518	1.9518
020	pork, bacon, oven cooked	pork fat		0.53	1.00	0.220	0.1166	0.1166	1.6750	0.8878	0.8878	1.7060	0.9042	0.9042	3.0850	1.6351	1.6351
021	pork roast, loin, oven cooked	pork fat		0.32	1.00	0.292	0.0934	0.0934	1.5990	0.5117	0.5117	4.3750	1.4000	1.4000	3.5320	1.1302	1.1302
028	frankfurters, (beef/beef and pork), boiled	beef fat	assume beef	0.27	1.00	2.104	0.5681	0.5681	8.5830	2.3174	2.3174	6.4370	1.7380	1.7380	8.7610	2.3655	2.3655
029	bologna	pork fat		0.29	1.00	0.996	0.2888	0.2888	5.2430	1.5205	1.5205	5.7240	1.6600	1.6600	11.1250	3.2263	3.2263
030	salami. lunch meat type, regular, not hard	pork fat		0.25	1.00	0.017	0.0043	0.0043	0.4420	0.1105	0.1105	1.0060	0.2515	0.2515	0.8520	0.2130	0.2130
039	pork and beans, canned	pork fat		0.03	1.00	1.024	0.0307	0.0307	4.5930	0.1378	0.1378	5.5360	0.1661	0.1661	11.1670	0.3350	0.3350
153	pork chow mein, homemade	pork fat		0.03	1.00	0.321	0.0096	0.0096	0.8090	0.0243	0.0243	2.0730	0.0622	0.0622	3.1190	0.0936	0.0936
206	pork, (st./jr.)	pork fat		0.06	1.00	1.489	0.0893	0.0893	0.0300	0.0018	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
210	high meat ham and vegetables, (st./jr.)	pork fat		0.04	1.00	3.303	0.1321	0.1321	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
213	vegetables with (bacon/ham), (st./jr.)	pork fat	bacon, strained	0.02	1.0C	8.112	0.1622	0.1622	0.1140	0.0023	0.0023	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		pork fat-total					2.0059	2.0059		8.1900	8.1900		10.2186	10.2186		15.2742	15.2742
024	chicken,drumstk/breast,breaded,fried w/add.fat,homemade	poultry		0.77	0.38	1.084	0.8347	0.3172	5.8820	4.5291	1.7211	9.4950	7.3112	2.7782	12.2340	9.4202	3.5797
025	chicken, oven roasted	poultry		0.96	0.29	1.257	1.2067	0.3499	4.8020	4.6099	1.3369	7.1950	6.9072	2.0031	8.4350	8.0976	2.3483
026	turkey breast, oven roasted	poultry		0.96	0.38	0.246	0.2362	0.0897	1.0700	1.0272	0.3903	3.5320	3.3907	1.2885	3.8810	3.7258	1.4158
150	chicken noodle casserole, homemade	poultry		0.12	0.45	0.288	0.0346	0.0156	1.2130	0.1456	0.0655	1.7410	0.2089	0.0940	4.1590	0.4991	0.2246
152	potpie, frozen, commercial, chicken, oven heated	poultry		0.26	0.17	0.142	0.0369	0.0063	1.7610	0.4579	0.0778	1.1420	0.2969	0.0505	2.1170	0.5504	0.0936
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	poultry		0.30	0.15	0.065	0.0195	0.0029	1.6920	0.5076	0.0761	1.3290	0.3987	0.0598	0.8830	0.2649	0.0397
155	chicken noodle soup, canned, reconstituted with water	poultry		0.03	0.14	6.835	0.2050	0.0287	17.8080	0.5342	0.0748	12.6120	0.3784	0.0530	7.0820	0.2125	0.0297
207	chicken/turkey, (st./jr.)	poultry	strained, chicken	0.92	0.16	5.128	4.7178	0.7548	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
208	high meat (chicken/turkey) and vegetables, (st./jr.)	poultry		0.40	0.16	6.200	2.4800	0.3968	0.2250	0.0900	0.0144	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
212	vegetables with (trukey/chicken), (st./jr.)	poultry	turkey, strained	0.18	0.04	5.412	0.9471	0.0379	0.0540	0.0095	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
214	chicken and noodles, (st./jr.)	poultry	strained	0.07	0.19	9.458	0.6621	0.1258	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
216	turkey and rice, (st./jr.)	poultry	strained	0.18	0.19	4.200	0.7560	0.1436	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		poultry-total					12.1365	2.2693		11.9110	3.7573		18.8920	6.3271		22.7704	7.7314
024	chicken,drumstk/breast,breaded,fried w/add.fat,homemade	poultry fat		0.06	1.00	1.084	0.0650	0.0650	5.8820	0.3529	0.3529	9.4950	0.5697	0.5697	12.2340	0.7340	0.7340
025	chicken, oven roasted	poultry fat		0.04	1.00	1.257	0.0503	0.0503	4.8020	0.1921	0.1921	7.1950	0.2878	0.2878	8.4350	0.3374	0.3374
026	turkey breast, oven roasted	poultry fat		0.04	1.00	0.246	0.0098	0.0098	1.0700	0.0428	0.0428	3.5320	0.1413	0.1413	3.8810	0.1552	0.1552
150	chicken noodle casserole, homemade	poultry fat		0.05	1.00	0.288	0.0144	0.0144	1.2130	0.0607	0.0607	1.7410	0.0871	0.0871	4.1590	0.2080	0.2080
152	potpie, frozen, commercial, chicken, oven heated	poultry fat		0.06	1.00	0.142	0.0085	0.0085	1.7610	0.1057	0.1057	1.4120	0.0847	0.0847	2.1170	0.1270	0.1270

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
017	pork, ham, cured, not canned, oven cooked	pork		0.78	0.46	6.8830	5.3687	2.4696	11.9680	9.3350	4.2941	6.5750	5.1285	2.3591	12.1630	9.4871	4.3641
018	pork chop, pan cooked with added fat	pork		0.70	0.35	5.8580	4.1006	1.4352	11.8260	8.2782	2.8974	4.5540	3.1878	1.1157	7.6250	5.3375	1.8681
019	pork sausage, (link/bulk), oven cooked	pork		0.54	0.35	2.9200	1.5768	0.5519	7.8160	4.2206	1.4772	2.8580	1.5433	0.5402	5.7360	3.0974	1.0841
020	pork, bacon, oven cooked	pork		0.47	0.77	2.0770	0.9762	0.7517	3.3730	1.5853	1.2207	2.6740	1.2568	0.9677	4.3570	2.0478	1.5768
021	pork roast, loin, oven cooked	pork		0.68	0.47	2.7860	1.8945	0.8904	4.5600	3.1008	1.4574	3.3940	2.3079	1.0847	6.1670	4.1936	1.9710
029	bologna	pork		0.71	0.16	5.4070	3.8390	0.6142	11.6740	8.2885	1.3262	4.2820	3.0402	0.4864	8.1890	5.8142	0.9303
030	salami, lunch meat type, regular, not hard	pork		0.75	0.26	0.5930	0.4448	0.1156	2.2200	1.6650	0.4329	4.0780	3.0585	0.7952	1.5520	1.1640	0.3026
039	pork and beans, canned	pork		0.06	0.15	5.5090	0.3305	0.0496	10.2340	0.6140	0.0921	4.9630	0.2978	0.0447	7.9010	0.4741	0.0711
153	pork chow mein, homemade	pork		0.23	0.24	3.8240	0.8795	0.2111	4.5130	1.0380	0.2491	2.9200	0.6716	0.1612	2.9040	0.6679	0.1603
206	pork, (st./jr.)	pork	strained	0.94	0.18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
210	high meat ham and vegetables, (st./jr.)	pork	strained	0.41	0.14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
213	vegetables with (bacon/ham), (st./jr.)	pork		0.24	0.10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		pork -total					19.4106	7.0893		38.1256	13.4471		20.4924	7.5549		32.2836	12.3284
017	pork, ham, cured, not canned, oven cooked	pork fat		0.22	1.00	6.8830	1.5143	1.5143	11.9680	2.6330	2.6330	6.5750	1.4465	1.4465	12.1630	2.6759	2.6759
018	pork chop, pan cooked with added fat	pork fat	assume not trimmed	0.26	1.00	5.5800	1.4508	1.4508	11.8260	3.0748	3.0748	4.5540	1.1840	1.1840	7.6250	1.9825	1.9825
019	pork sausage, (link/bulk), oven cooked	pork fat		0.46	1.00	2.9200	1.3432	1.3432	7.8160	3.5954	3.5954	2.8580	1.3147	1.3147	5.7360	2.6386	2.6386
020	pork, bacon, oven cooked	pork fat		0.53	1.00	2.0770	1.1008	1.1008	3.3730	1.7877	1.7877	2.6740	1.4172	1.4172	4.3570	2.3092	2.3092
021	pork roast, loin, oven cooked	pork fat		0.32	1.00	2.7860	0.8915	0.8915	4.5600	1.4592	1.4592	3.3940	1.0861	1.0861	6.1670	1.9734	1.9734
028	frankfurters, (beef/beef and pork), boiled	beef fat	assume beef	0.27	1.00	5.2320	1.4126	1.4126	8.5910	2.3196	2.3196	3.7530	1.0133	1.0133	5.3520	1.4450	1.4450
029	bologna	pork fat		0.29	1.00	5.4070	1.5680	1.5680	11.6740	3.3855	3.3855	4.2820	1.2418	1.2418	8.1890	2.3748	2.3748
030	salami, lunch meat type, regular, not hard	pork fat		0.25	1.00	0.5930	0.1483	0.1483	2.2200	0.5550	0.5550	4.0780	1.0195	1.0195	1.5520	0.3880	0.3880
039	pork and beans, canned	pork fat		0.03	1.00	5.5090	0.1653	0.1653	10.2340	0.3070	0.3070	4.9630	0.1489	0.1489	7.9010	0.2370	0.2370
153	pork chow mein, homemade	pork fat		0.03	1.00	3.8240	0.1147	0.1147	4.5130	0.1354	0.1354	2.9200	0.0876	0.0876	2.9040	0.0871	0.0871
206	pork, (st./jr.)	pork fat		0.06	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
210	high meat ham and vegetables, (st./jr.)	pork fat		0.04	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
213	vegetables with (bacon/ham), (st./jr.)	pork fat	bacon, strained	0.02	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		pork fat-total					9.7095	9.7095		19.2524	19.2524		9.9596	9.9596		16.1116	16.1116
024	chicken,drumstk/breast,breaded,fried w/add.fat,homemade	poultry		0.77	0.38	8.9940	6.9254	2.6316	12.4750	9.6058	3.6502	7.3440	5.6549	2.1489	9.2560	7.1271	2.7083
025	chicken, oven roasted	poultry		0.96	0.29	9.7190	9.3302	2.7058	10.5090	10.0886	2.9257	11.0170	10.5763	3.0671	11.0780	10.6349	3.0841
026	turkey breast, oven roasted	poultry		0.96	0.38	1.4720	1.4131	0.5370	5.7430	5.5133	2.0950	2.1640	2.0774	0.7894	3.7390	3.5894	1.3640
150	chicken noodle casserole, homemade	poultry		0.12	0.45	2.3550	0.2826	0.1272	5.2490	0.6299	0.2834	2.1530	0.2584	0.1163	1.7760	0.2131	0.0959
152	potpie, frozen, commercial, chicken, oven heated	poultry		0.26	0.17	1.3440	0.3494	0.0594	2.0880	0.5429	0.0923	1.4940	0.3884	0.0660	1.3920	0.3619	0.0615
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	poultry		0.30	0.15	1.3990	0.4197	0.0630	1.2230	0.3669	0.0550	1.2620	0.3786	0.0568	1.9460	0.5838	0.0876
155	chicken noodle soup, canned, reconstituted with water	poultry		0.03	0.14	7.0920	0.2128	0.0298	7.5110	0.2253	0.0315	8.2750	0.2483	0.0348	14.2020	0.4261	0.0596
207	chicken/turkey, (st./jr.)	poultry	strained, chicken	0.92	0.16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
208	high meat (chicken/turkey) and vegetables, (st./jr.)	poultry		0.40	0.16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
212	vegetables with (trukey/chicken), (st./jr.)	poultry	turkey, strained	0.18	0.04	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
214	chicken and noodles, (st./jr.)	poultry	strained	0.07	0.19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
216	turkey and rice, (st./jr.)	poultry	strained	0.18	0.19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		poultry-total					18.9332	6.1537		26.9727	9.1333		19.5823	6.2793		22.9363	7.4611
024	chicken,drumstk/breast,breaded,fried w/add.fat,homemade	poultry fat		0.06	1.00	8.9940	0.5396	0.5396	12.4750	0.7485	0.7485	7.3440	0.4406	0.4406	9.2560	0.5554	0.5554
025	chicken, oven roasted	poultry fat		0.04	1.00	9.7190	0.3888	0.3888	10.5090	0.4204	0.4204	11.0170	0.4407	0.4407	11.0780	0.4431	0.4431
026	turkey breast, oven roasted	poultry fat		0.04	1.00	1.4720	0.0589	0.0589	5.7430	0.2297	0.2297	2.1640	0.0866	0.0866	3.7390	0.1496	0.1496
150	chicken noodle casserole, homemade	poultry fat		0.05	1.00	2.3550	0.1178	0.1178	5.2490	0.2625	0.2625	2.1530	0.1077	0.1077	1.7760	0.0888	0.0888
152	potpie, frozen, commercial, chicken, oven heated	poultry fat		0.06	1.00	1.3440	0.0806	0.0806	2.0880	0.1253	0.1253	1.4940	0.0896	0.0896	1.3920	0.0835	0.0835

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	poultry fat		0.04	1.00	0.065	0.0026	0.0026	1.6920	0.0677	0.0677	1.3290	0.0532	0.0532	0.8830	0.0353	0.0353
207	chicken/turkey, (st./jr.)	poultry fat		0.08	1.00	5.128	0.4102	0.4102	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
208	high meat (chicken/turkey) and vegetables, (st./jr.)	poultry fat		0.04	1.00	6.200	0.2480	0.2480	0.2250	0.0090	0.0090	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
212	vegetables with (trukey/chicken), (st./jr.)	poultry fat		0.02	1.00	5.412	0.1082	0.1082	0.0540	0.0011	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
214	chicken and noodles, (st./jr.)	poultry fat		0.01	1.00	9.458	0.0946	0.0946	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
216	turkey and rice, (st./jr.)	poultry fat		0.02	1.00	4.200	0.0840	0.0840	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		poultry fat-total					1.0957	1.0957		0.8319	0.8319		1.2237	1.2237		1.5970	1.5970
031	(cod/haddock) fillet, (fresh/frozen), oven cooked	fish	haddock, fresh	1.00	0.24	0.853	0.8530	0.2047	2.2610	2.2610	0.5426	4.6780	4.6780	1.1227	5.8020	5.8020	1.3925
032	tuna, canned in oil, drained	fish		0.92	0.32	0.300	0.2760	0.0883	1.4710	1.3533	0.4331	3.3560	3.0875	0.9880	2.6500	2.4380	0.7802
033	shrimp(fresh/frozen),breaded&fried w/add. fat,homemade	fish	fish fat	0.02	1.00	0.000	0.0000	0.0000	0.1240	0.0025	0.0025	0.7600	0.0152	0.0152	1.1970	0.0239	0.0239
033	shrimp(fresh/frozen),breaded&fried w/add. fat,homemade	fish		0.74	0.20	0.000	0.0000	0.0000	0.1240	0.0918	0.0184	0.7600	0.5624	0.1125	1.1970	0.8858	0.1772
034	fish sticks, commercial, frozen, oven cooked	fish		0.63	0.28	0.259	0.1632	0.0457	1.1560	0.7283	0.2039	1.7070	1.0754	0.3011	1.7160	1.0811	0.3027
		fish-total					1.2922	0.3387		4.4368	1.2005		9.4185	2.5395		10.2308	2.6764
001	whole milk, fluid	dairy		0.97	0.08	254.846	247.2006	19.7760	249.2850	241.8064	19.3445	227.3790	220.5576	17.6446	371.8620	360.7061	28.8565
002	low-fat milk 2% fat, fluid	dairy		0.98	0.08	106.631	104.4984	8.3599	68.7250	67.3505	5.3880	61.2230	59.9985	4.7999	100.5020	98.4920	7.8794
003	chocolate milk, fluid, low-fat milk	dairy		0.92	0.08	1.725	1.5870	0.1270	10.6730	9.8192	0.7855	38.8010	35.6969	2.8558	61.0540	56.1697	4.4936
004	skim milk, fluid	dairy		1.00	0.09	33.939	33.9390	3.0545	19.4830	19.4830	1.7535	17.5640	17.5640	1.5808	19.6490	19.6490	1.7684
005	buttermilk, fluid	dairy		0.99	0.08	0.209	0.2069	0.0166	0.4880	0.4831	0.0386	0.0000	0.0000	0.0000	0.6560	0.6494	0.0520
006	yogurt, plain, low-fat	dairy	with added milk solids	0.98	0.13	0.646	0.6331	0.0823	1.0950	1.0731	0.1395	1.0640	1.0427	0.1356	0.4300	0.4214	0.0548
007	milkshake, chocolate, fast-food type	dairy		0.79	0.12	0.451	0.3563	0.0428	1.2860	1.0159	0.1219	5.6250	4.4438	0.5333	9.0970	7.1866	0.8624
008	evaporated milk, canned	dairy		0.92	0.18	6.196	5.7003	1.0261	1.8740	1.7241	0.3103	0.7100	0.6532	0.1176	0.4330	0.3984	0.0717
009	yogurt, sweetened, strawberry, pre-stirred	dairy	low-fat milk	0.86	0.08	1.325	1.1395	0.0912	1.7490	1.5041	0.1203	1.0430	0.8970	0.0718	0.6490	0.5581	0.0447
010	cheese, American, processed	dairy		0.68	0.35	1.382	0.9398	0.3289	5.4630	3.7148	1.3002	4.7890	3.2565	1.1398	7.7870	5.2952	1.8533
011	cottage cheese, creamed, 4% milkfat	dairy		0.96	0.16	2.098	2.0141	0.3223	1.4700	1.4112	0.2258	2.2090	2.1206	0.3393	1.7070	1.6387	0.2622
012	cheese, Cheddar, (sharp/mild)	dairy		0.68	0.40	0.194	0.1319	0.0528	1.8150	1.2342	0.4937	3.3260	2.2617	0.9047	3.1850	2.1658	0.8663
035	eggs, scrambled with added milk and fat	dairy	assume whole milk	0.20	0.08	6.374	1.2748	0.1020	13.0880	2.6176	0.2094	7.8550	1.5710	0.1257	12.0730	2.4146	0.1932
060	cornbread, southern style, homemade	dairy		0.29	0.08	0.877	0.2543	0.0203	3.2590	0.9451	0.0756	4.4320	1.2853	0.1028	6.8760	1.9940	0.1595
065	muffins (blueberry/plain)	dairy		0.11	0.08	0.039	0.0043	0.0003	0.6870	0.0756	0.0060	0.9140	0.1005	0.0080	0.7240	0.0796	0.0064
068	pancakes made from mix w/addition of egg, milk and oil	dairy	whole milk	0.32	0.31	1.075	0.3440	0.1066	5.8330	1.8666	0.5786	5.7260	1.8323	0.5680	8.0120	2.5638	0.7948
135	mashed potatoes w/marg. & milk, prepared from instant	dairy	milk	0.06	0.08	7.389	0.4433	0.0355	9.8790	0.5927	0.0474	15.0040	0.9002	0.0720	24.5260	1.4716	0.1177
139	scalloped potatoes, homemade	dairy	milk	0.20	0.08	1.023	0.2046	0.0164	2.0490	0.4098	0.0328	4.1450	0.8290	0.0663	5.8710	1.1742	0.0939
144	pizza, cheese, frozen, commercial, heated	dairy	cheese	0.10	0.08	0.484	0.0484	0.0039	3.1980	0.3198	0.0256	12.4450	1.2445	0.0996	39.9780	3.9978	0.3198
146	macaroni and cheese, prepared from box mix	dairy	milk	0.13	0.08	3.545	0.4609	0.0369	7.4810	0.9725	0.0778	8.4490	1.0984	0.0879	12.0250	1.5633	0.1251
146	macaroni and cheese, prepared from box mix	dairy	cheese	0.15	0.35	3.545	0.5318	0.1861	7.4810	1.1222	0.3928	8.4490	1.2674	0.4436	12.0250	1.8038	0.6313
150	chicken noodle casserole, homemade	dairy	cheese	0.01	0.84	0.288	0.0029	0.0024	1.2130	0.0121	0.0102	1.7410	0.0174	0.0146	4.1590	0.0416	0.0349
150	chicken noodle casserole, homemade	dairy	milk	0.09	0.08	0.288	0.0259	0.0021	1.2130	0.1092	0.0087	1.7410	0.1567	0.0125	4.1590	0.3743	0.0299
151	lasagne, homemade	dairy	cheese	0.24	0.31	0.261	0.0626	0.0194	1.1370	0.2729	0.0846	2.5540	0.6130	0.1900	4.4070	1.0577	0.3279
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	dairy	milk	0.07	0.08	0.065	0.0046	0.0004	1.6920	0.1184	0.0095	1.3290	0.0930	0.0074	0.8830	0.0618	0.0049
156	tomato soup, canned, reconstituted with whole milk	dairy	milk	0.39	0.08	3.052	1.1903	0.0952	5.7570	2.2452	0.1796	6.0000	2.3400	0.1872	5.4890	2.1407	0.1713
160	white sauce, medium, homemade	dairy	milk	0.79	0.08	0.346	0.2733	0.0219	0.4670	0.3689	0.0295	0.5250	0.4148	0.0332	1.4300	1.1297	0.0904
167	cream, half and half, fluid	dairy	cream & milk	0.90	0.12	0.015	0.0135	0.0016	0.5410	0.4869	0.0584	1.0820	0.9738	0.1169	0.9530	0.8577	0.1029
174	ice cream, chocolate	dairy		0.75	0.08	1.490	1.1175	0.0894	9.5790	7.1843	0.5747	15.6850	11.7638	0.9411	23.0440	17.2830	1.3826
175	pudding, chocolate, instant, made with whole milk	dairy		0.16	0.08	1.280	0.2048	0.0164	3.4870	0.5579	0.0446	3.4120	0.5459	0.0437	6.5920	1.0547	0.0844
176	ice cream sandwich	dairy		0.10	0.08	0.054	0.0054	0.0004	1.1640	0.1164	0.0093	1.9210	0.1921	0.0154	2.5240	0.2524	0.0202
177	ice milk, vanilla	dairy		0.80	0.20	0.116	0.0928	0.0186	1.7240	1.3792	0.2758	2.8690	2.2952	0.4590	5.5750	4.4600	0.8920
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	dairy		0.06	0.08	0.170	0.0102	0.0008	2.3260	0.1396	0.0112	6.7310	0.4039	0.0323	8.5340	0.5120	0.0410
179	yellow cake prep. from mix w/white icing prep. from mix	dairy		0.06	0.08	0.634	0.0380	0.0030	3.1700	0.1902	0.0152	8.4330	0.5060	0.0405	12.1270	0.7276	0.0582

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	poultry fat		0.04	1.00	1.3990	0.0560	0.0560	1.2230	0.0489	0.0489	1.2620	0.0505	0.0505	1.9460	0.0778	0.0778
207	chicken/turkey, (st./jr.)	poultry fat		0.08	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
208	high meat (chicken/turkey) and vegetables, (st./jr.)	poultry fat		0.04	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
212	vegetables with (trukey/chicken), (st./jr.)	poultry fat		0.02	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
214	chicken and noodles, (st./jr.)	poultry fat		0.01	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
216	turkey and rice, (st./jr.)	poultry fat		0.02	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		poultry fat-total					1.2416	1.2416		1.8352	1.8352		1.2157	1.2157		1.3982	1.3982
031	(cod/haddock) fillet, (fresh/frozen), oven cooked	fish	haddock, fresh	1.00	0.24	6.2330	6.2330	1.4959	9.9860	9.9860	2.3966	8.3630	8.3630	2.0071	11.2350	11.2350	2.6964
032	tuna, canned in oil, drained	fish		0.92	0.32	4.2530	3.9128	1.2521	4.4570	4.1004	1.3121	3.7310	3.4325	1.0984	3.1100	2.8612	0.9156
033	shrimp(fresh/frozen),breaded&fried w/add. fat,homemade	fish	fish fat	0.02	1.00	2.6550	0.0531	0.0531	3.4720	0.0694	0.0694	1.9740	0.0395	0.0395	1.8440	0.0369	0.0369
033	shrimp(fresh/frozen),breaded&fried w/add. fat,homemade	fish		0.74	0.20	2.6550	1.9647	0.3929	3.4720	2.5693	0.5139	1.9740	1.4608	0.2922	1.8440	1.3646	0.2729
034	fish sticks, commercial, frozen, oven cooked	fish		0.63	0.28	1.7420	1.0975	0.3073	2.1410	1.3488	0.3777	1.0890	0.6861	0.1921	1.0530	0.6634	0.1857
		fish-total					13.2610	3.5013		18.0740	4.6697		13.9818	3.6293		16.1610	4.1075
001	whole milk, fluid	dairy		0.97	0.08	104.4840	101.3495	8.1080	167.8770	162.8407	13.0273	88.0130	85.3726	6.8298	127.0260	123.2152	9.8572
002	low-fat milk 2% fat, fluid	dairy		0.98	0.08	52.9910	51.9312	4.1545	73.8430	72.3661	5.7893	34.7000	34.0060	2.7205	50.1440	49.1411	3.9313
003	chocolate milk, fluid, low-fat milk	dairy		0.92	0.08	10.3840	9.5533	0.7643	14.3360	13.1891	1.0551	3.7360	3.4371	0.2750	5.0710	4.6653	0.3732
004	skim milk, fluid	dairy		1.00	0.09	15.0100	15.0100	1.3509	13.2830	13.2830	1.1955	20.6700	20.6700	1.8603	19.9710	19.9710	1.7974
005	buttermilk, fluid	dairy		0.99	0.08	1.1360	1.1246	0.0900	1.6130	1.5969	0.1277	5.6980	5.6410	0.4513	8.6970	8.6100	0.6888
006	yogurt, plain, low-fat	dairy	with added milk solids	0.98	0.13	2.5080	2.4578	0.3195	1.7920	1.7562	0.2283	1.3400	1.3132	0.1707	0.5440	0.5331	0.0693
007	milkshake, chocolate, fast-food type	dairy		0.79	0.12	3.1250	2.4688	0.2963	4.3490	3.4357	0.4123	0.3280	0.2591	0.0311	1.0830	0.8556	0.1027
008	evaporated milk, canned	dairy		0.92	0.18	0.4280	0.3938	0.0709	0.9680	0.8906	0.1603	1.3420	1.2346	0.2222	3.0130	2.7720	0.4990
009	yogurt, sweetened, strawberry, pre-stirred	dairy	low-fat milk	0.86	0.08	3.0960	2.6626	0.2130	2.9320	2.5215	0.2017	2.2030	1.8946	0.1516	0.2440	0.2098	0.0168
010	cheese, American, processed	dairy		0.68	0.35	6.4480	4.3846	1.5346	8.9100	6.0588	2.1206	3.7090	2.5221	0.8827	5.0560	3.4381	1.2033
011	cottage cheese, creamed, 4% milkfat	dairy		0.96	0.16	4.6980	4.5101	0.7216	2.7490	2.6390	0.4222	7.0640	6.7814	1.0850	6.4310	6.1738	0.9878
012	cheese, Cheddar, (sharp/mild)	dairy		0.68	0.40	5.4820	3.7278	1.4911	10.7460	7.3073	2.9229	3.9300	2.6724	1.0690	4.8300	3.2844	1.3138
035	eggs, scrambled with added milk and fat	dairy	assume whole milk	0.20	0.08	9.7830	1.9566	0.1565	15.0470	3.0094	0.2408	10.0850	2.0170	0.1614	12.5790	2.5158	0.2013
060	cornbread, southern style, homemade	dairy		0.29	0.08	3.8690	1.1220	0.0898	8.8500	2.5665	0.2053	8.3130	2.4108	0.1929	11.9270	3.4588	0.2767
065	muffins (blueberry/plain)	dairy		0.11	0.08	0.9470	0.1042	0.0083	0.9450	0.1040	0.0083	1.0140	0.1115	0.0089	0.8380	0.0922	0.0074
068	pancakes made from mix w/addition of egg, milk and oil	dairy	whole milk	0.32	0.31	4.4820	1.4342	0.4446	6.9760	2.2323	0.6920	3.6180	1.1578	0.3589	6.2960	2.0147	0.6246
135	mashed potatoes w/marg. & milk, prepared from instant	dairy	milk	0.06	0.08	11.6100	0.6966	0.0557	18.8350	1.1301	0.0904	10.4050	0.6243	0.0499	17.0150	1.0209	0.0817
139	scalloped potatoes, homemade	dairy	milk	0.20	0.08	5.1640	1.0328	0.0826	7.4240	1.4848	0.1188	5.3580	1.0716	0.0857	7.6840	1.5368	0.1229
144	pizza, cheese, frozen, commercial, heated	dairy	cheese	0.10	0.08	9.2070	0.9207	0.0737	13.5180	1.3518	0.1081	2.0030	0.2003	0.0160	2.2310	0.2231	0.0176
146	macaroni and cheese, prepared from box mix	dairy	milk	0.13	0.08	7.4000	0.9620	0.0770	8.6990	1.1309	0.0905	5.1060	0.6638	0.0531	4.4730	0.5815	0.0465
146	macaroni and cheese, prepared from box mix	dairy	cheese	0.15	0.35	7.4000	1.1100	0.3885	8.6990	1.3048	0.4567	5.1060	0.7659	0.2681	4.4730	0.6709	0.2348
150	chicken noodle casserole, homemade	dairy	cheese	0.01	0.84	2.3550	0.0236	0.0198	5.2490	0.0525	0.0441	2.1530	0.0215	0.0181	1.7760	0.0178	0.0149
150	chicken noodle casserole, homemade	dairy	milk	0.09	0.08	2.3550	0.2120	0.0170	5.2490	0.4724	0.0378	2.1530	0.1938	0.0155	1.7760	0.1598	0.0128
151	lasagne, homemade	dairy	cheese	0.24	0.31	3.0440	0.7306	0.2265	5.1430	1.2343	0.3826	1.5230	0.3655	0.1133	1.9470	0.4673	0.1449
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	dairy	milk	0.07	0.08	1.3990	0.0979	0.0078	1.2230	0.0856	0.0068	1.2620	0.0883	0.0071	1.9460	0.1362	0.0109
156	tomato soup, canned, reconstituted with whole milk	dairy	milk	0.39	0.08	10.8540	4.2331	0.3386	11.1120	4.3337	0.3467	11.7070	4.5657	0.3653	11.6200	4.5318	0.3625
160	white sauce, medium, homemade	dairy	milk	0.79	0.08	0.9790	0.7734	0.0619	1.7100	1.3509	0.1081	0.7340	0.5799	0.0464	1.8370	1.4512	0.1161
167	cream, half and half, fluid	dairy	cream & milk	0.90	0.12	1.7630	1.5867	[illegible]	2.9200	2.6280	0.3154	3.0450	2.7405	0.3289	4.2840	3.8556	0.4627
174	ice cream, chocolate	dairy		0.75	0.08	9.3590	7.0193	[illegible]	13.4990	10.1243	0.8099	11.3030	8.4773	0.6782	17.7550	13.3163	1.0653
175	pudding, chocolate, instant, made with whole milk	dairy		0.16	0.08	2.6720	0.4275	[illegible]	3.8430	0.6149	0.0492	4.7000	0.7520	0.0602	5.1830	0.8293	0.0663
176	ice cream sandwich	dairy		0.10	0.08	0.6610	0.0661	0.0053	0.5560	0.0556	0.0044	0.3690	0.0369	0.0030	0.5840	0.0584	0.0047
177	ice milk, vanilla	dairy		0.80	0.20	1.8990	1.5192	0.3038	2.0470	1.6376	0.3275	2.9220	2.3376	0.4675	2.4560	1.9648	0.3930
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	dairy		0.06	0.08	3.3420	0.2005	0.0160	5.9130	0.3548	0.0284	1.9840	0.1190	0.0095	3.4690	0.2081	0.0167
179	yellow cake prep. from mix w/white icing prep. from mix	dairy		0.06	0.08	5.5890	0.3353	0.0268	8.9790	0.5387	0.0431	6.8930	0.4136	0.0331	8.2560	0.4954	0.0396

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
180	coffeecake, (ready-to-eat/frozen)	dairy		0.25	0.08	0.052	0.0130	0.0010	0.2910	0.0728	0.0058	1.2450	0.3113	0.0249	0.9190	0.2298	0.0184
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	dairy	non-fat	0.03	0.08	0.516	0.0155	0.0012	2.3650	0.0710	0.0057	4.0180	0.1205	0.0096	6.6590	0.1998	0.0160
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	dairy		0.21	0.08	0.119	0.0250	0.0020	0.5470	0.1149	0.0092	2.0850	0.4378	0.0350	5.1720	1.0861	0.0869
186	pumpkin pie, frozen, heated	dairy	evaporated milk	0.18	0.21	0.440	0.0792	0.0166	1.0020	0.1804	0.0379	3.0270	0.5449	0.1144	3.2390	0.5830	0.1224
188	candy, carmels	dairy		0.16	0.08	0.075	0.0120	0.0010	1.8790	0.3006	0.0241	2.8520	0.4563	0.0365	2.4330	0.3893	0.0311
202	milk-based infant formula w/iron,canned,ready-to serve	dairy		0.31	0.08	47.728	14.7957	1.1837	0.6820	0.2114	0.0169	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
203	milk-based infant formula w/o iron,canned,ready-to-serv	dairy		0.31	0.08	81.931	25.3986	2.0319	1.9000	0.5890	0.0471	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
204	infant mixed cereal, prepared from dry with whole milk	dairy		0.78	0.08	51.842	40.4368	3.2349	0.1470	0.1147	0.0092	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
232	pudding/custard, any flavor, (st./jr.)	dairy	non-fat dry milk	0.02	0.99	8.326	0.1665	0.1649	0.0150	0.0003	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		dairy-total					485.8973	40.6970		374.3778	32.9356		380.8075	34.0111		602.8343	53.0223
001	whole milk, fluid	dairy fat	3.3% fat	0.03	1.00	254.846	7.6454	7.6454	249.2850	7.4785	7.4785	227.3790	6.8214	6.8214	371.8620	11.1559	11.1559
002	low-fat milk 2% fat, fluid	dairy fat		0.02	1.00	106.631	2.1326	2.1326	68.7250	1.3745	1.3745	61.2230	1.2245	1.2245	100.5020	2.0100	2.0100
003	chocolate milk, fluid, low-fat milk	dairy fat	2.0% fat	0.02	1.00	1.725	0.0345	0.0345	10.6730	0.2135	0.2135	38.8010	0.7760	0.7760	61.0540	1.2211	1.2211
005	buttermilk, fluid	dairy fat	1.0% fat	0.01	1.00	0.209	0.0021	0.0021	0.4860	0.0049	0.0049	0.0000	0.0000	0.0000	0.6560	0.0066	0.0066
006	yogurt, plain, low-fat	dairy fat		0.02	1.00	0.646	0.0129	0.0129	1.0950	0.0219	0.0219	1.0640	0.0213	0.0213	0.4300	0.0086	0.0086
007	milkshake, chocolate, fast-food type	dairy fat		0.02	1.00	0.451	0.0090	0.0090	1.2860	0.0257	0.0257	5.6250	0.1125	0.1125	9.0970	0.1819	0.1819
008	evaporated milk, canned	dairy fat		0.08	1.00	6.196	0.4957	0.4957	1.8740	0.1499	0.1499	0.7100	0.0568	0.0568	0.4330	0.0346	0.0346
009	yogurt, sweetened, strawberry, pre-stirred	dairy fat		0.01	1.00	1.325	0.0133	0.0133	1.7490	0.0175	0.0175	1.0430	0.0104	0.0104	0.6490	0.0065	0.0065
010	cheese, American, processed	dairy fat		0.32	1.00	1.382	0.4422	0.4422	5.4630	1.7482	1.7482	4.7890	1.5325	1.5325	7.7870	2.4918	2.4918
011	cottage cheese, creamed, 4% milkfat	dairy fat		0.04	1.00	2.098	0.0839	0.0839	1.4700	0.0588	0.0588	2.2090	0.0884	0.0884	1.7070	0.0683	0.0683
012	cheese, Cheddar, (sharp/mild)	dairy fat		0.32	1.00	0.194	0.0621	0.0621	1.8150	0.5808	0.5808	3.3260	1.0643	1.0643	3.1850	1.0192	1.0192
035	eggs, scrambled with added milk and fat	dairy fat	assume whole milk	0.01	1.00	6.374	0.0637	0.0637	13.0880	0.1309	0.1309	7.8550	0.0786	0.0786	12.0730	0.1207	0.1207
060	cornbread, southern style, homemade	dairy fat		0.01	1.00	0.877	0.0088	0.0088	3.2590	0.0326	0.0326	4.4320	0.0443	0.0443	6.8760	0.0688	0.0688
065	muffins (blueberry/plain)	dairy fat		0.03	1.00	0.039	0.0012	0.0012	0.6870	0.0206	0.0206	0.9140	0.0274	0.0274	0.7240	0.0217	0.0217
068	pancakes made from mix w/addition of egg, milk and oil	dairy fat		0.02	1.00	1.075	0.0215	0.0215	5.8330	0.1167	0.1167	5.7260	0.1145	0.1145	8.0120	0.1602	0.1602
135	mashed potatoes w/marg. & milk, prepared from instant	dairy fat	milk	0.01	1.00	7.389	0.0739	0.0739	9.8790	0.0988	0.0988	15.0040	0.1500	0.1500	24.5260	0.2453	0.2453
139	scalloped potatoes, homemade	dairy fat	milk	0.01	1.00	1.023	0.0102	0.0102	2.0490	0.0205	0.0205	4.1450	0.0414	0.0414	5.8710	0.0587	0.0587
144	pizza, cheese, frozen, commercial, heated	dairy fat	cheese	0.08	1.00	0.484	0.0387	0.0387	3.1980	0.2558	0.2558	12.4450	0.9956	0.9956	39.9780	3.1982	3.1982
146	macaroni and cheese, prepared from box mix	dairy fat	milk	0.01	1.00	3.545	0.0355	0.0355	7.4810	0.0748	0.0748	8.4490	0.0845	0.0845	12.0250	0.1203	0.1203
146	macaroni and cheese, prepared from box mix	dairy fat	cheese	0.08	1.00	3.545	0.2836	0.2836	7.4810	0.5985	0.5985	8.4490	0.6759	0.6759	12.0250	0.9620	0.9620
150	chicken noodle casserole, homemade	dairy fat	milk, cheese	0.02	1.00	0.288	0.0058	0.0058	1.2130	0.0243	0.0243	1.7410	0.0348	0.0348	4.1590	0.0832	0.0832
151	lasagne, homemade	dairy fat		0.12	1.00	0.261	0.0313	0.0313	1.1370	0.1364	0.1364	2.5540	0.3065	0.3065	4.4070	0.5288	0.5288
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	dairy fat	milk	0.01	1.00	0.065	0.0007	0.0007	1.6920	0.0169	0.0169	1.3290	0.0133	0.0133	0.8830	0.0088	0.0088
156	tomato soup, canned, reconstituted with whole milk	dairy fat		0.03	1.00	3.052	0.0916	0.0916	5.7570	0.1727	0.1727	6.0000	0.1800	0.1800	5.4890	0.1647	0.1647
160	white sauce, medium, homemade	dairy fat	butter, milk	0.13	1.00	0.346	0.0450	0.0450	0.4670	0.0607	0.0607	0.5250	0.0683	0.0683	1.4300	0.1859	0.1859
164	butter, stick type	dairy fat	regular	1.00	0.84	0.367	0.3670	0.3083	1.2140	1.2140	1.0198	1.6910	1.6910	1.4204	2.4470	2.4470	2.0555
167	cream, half and half, fluid	dairy fat		0.10	1.00	0.015	0.0015	0.0015	0.5410	0.0541	0.0541	1.0820	0.1082	0.1082	0.9530	0.0953	0.0953
174	ice cream, chocolate	dairy fat		0.10	1.00	1.490	0.1490	0.1490	9.5790	0.9579	0.9579	15.6850	1.5685	1.5685	23.0440	2.3044	2.3044
175	pudding, chocolate, instant, made with whole milk	dairy fat		0.03	1.00	1.280	0.0384	0.0384	3.4870	0.1046	0.1046	3.4120	0.1024	0.1024	6.5920	0.1978	0.1978
176	ice cream sandwich	dairy fat		0.02	1.00	0.054	0.0011	0.0011	1.1640	0.0233	0.0233	1.9210	0.0384	0.0384	2.5240	0.0505	0.0505
177	ice milk, vanilla	dairy fat		0.05	1.00	0.116	0.0058	0.0058	1.7240	0.0862	0.0862	2.8690	0.1435	0.1435	5.5750	0.2788	0.2788
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	dairy fat		0.04	1.00	0.170	0.0068	0.0068	2.3260	0.0930	0.0930	6.7310	0.2692	0.2692	8.5340	0.3414	0.3414
179	yellow cake prep. from mix w/white icing prep. from mix	dairy fat		0.04	1.00	0.634	0.0254	0.0254	3.1700	0.1268	0.1268	8.4330	0.3373	0.3373	12.1270	0.4851	0.4851
180	coffeecake, (ready-to-eat/frozen)	dairy fat		0.02	1.00	0.052	0.0010	0.0010	0.2910	0.0058	0.0058	1.2450	0.0249	0.0249	0.9190	0.0184	0.0184
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	dairy fat		0.01	1.00	0.119	0.0012	0.0012	0.5470	0.0055	0.0055	2.0850	0.0209	0.0209	5.1720	0.0517	0.0517
186	pumpkin pie, frozen, heated	dairy fat		0.02	1.00	0.440	0.0088	0.0088	1.0020	0.0200	0.0200	3.0270	0.0605	0.0605	3.2390	0.0648	0.0648
188	candy, carmels	dairy fat		0.03	1.00	0.075	0.0023	0.0023	1.8790	0.0564	0.0564	2.8520	0.0856	0.0856	2.4330	0.0730	0.0730
202	milk-based infant formula w/iron,canned,ready-to serve	dairy fat		0.19	1.00	47.728	9.0683	9.0683	0.6820	0.1296	0.1296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
180	coffeecake, (ready-to-eat/frozen)	dairy		0.25	0.08	0.7440	0.1860	0.0149	1.3960	0.3490	0.0279	1.1990	0.2998	0.0240	1.4900	0.3725	0.0298
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	dairy	non-fat	0.03	0.08	3.6910	0.1107	0.0089	5.6830	0.1705	0.0136	2.3070	0.0692	0.0055	4.7270	0.1418	0.0113
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	dairy		0.21	0.08	2.0300	0.4263	0.0341	3.6500	0.7665	0.0613	2.5210	0.5294	0.0424	3.1590	0.6634	0.0531
186	pumpkin pie, frozen, heated	dairy	evaporated milk	0.18	0.21	3.3030	0.5945	0.1249	5.5980	1.0076	0.2116	4.8070	0.8653	0.1817	5.2000	0.9360	0.1966
188	candy, caramels	dairy		0.16	0.08	1.6330	0.2613	0.0209	4.0590	0.6494	0.0520	1.1240	0.1798	0.0144	1.1850	0.1896	0.0152
202	milk-based infant formula w/iron,canned,ready-to serve	dairy		0.31	0.08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
203	milk-based infant formula w/o iron,canned,ready-to-serv	dairy		0.31	0.08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
204	infant mixed cereal, prepared from dry with whole milk	dairy		0.78	0.08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
232	pudding/custard, any flavor, (st./jr.)	dairy	non-fat dry milk	0.02	0.99	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		dairy-total					227.7170	22.5046		328.6258	32.5447		197.4623	19.3580		264.7795	25.4705
001	whole milk, fluid	dairy fat	3.3% fat	0.03	1.00	104.4840	3.1345	3.1345	167.8770	5.0363	5.0363	88.0130	2.6404	2.6404	127.0260	3.8108	3.8108
002	low-fat milk 2% fat, fluid	dairy fat		0.02	1.00	52.9910	1.0598	1.0598	73.8430	1.4769	1.4769	34.7000	0.6940	0.6940	50.1440	1.0029	1.0029
003	chocolate milk, fluid, low-fat milk	dairy fat	2.0% fat	0.02	1.00	10.3840	0.2077	0.2077	14.3360	0.2867	0.2867	3.7360	0.0747	0.0747	5.0710	0.1014	0.1014
005	buttermilk, fluid	dairy fat	1.0% fat	0.01	1.00	1.1360	0.0114	0.0114	1.6130	0.0161	0.0161	5.6980	0.0576	0.0570	8.6970	0.0870	0.0870
006	yogurt, plain, low-fat	dairy fat		0.02	1.00	2.5080	0.0502	0.0502	1.7920	0.0358	0.0358	1.3400	0.0268	0.0268	0.5440	0.0109	0.0109
007	milkshake, chocolate, fast-food type	dairy fat		0.02	1.00	3.1250	0.0625	0.0625	4.3490	0.0870	0.0870	0.3280	0.0066	0.0066	1.0830	0.0217	0.0217
008	evaporated milk, canned	dairy fat		0.08	1.00	0.4280	0.0342	0.0342	0.9680	0.0774	0.0774	1.3420	0.1074	0.1074	3.0130	0.2410	0.2410
009	yogurt, sweetened, strawberry, pre-stirred	dairy fat		0.01	1.00	3.0960	0.0310	0.0310	2.9320	0.0293	0.0293	2.2030	0.0220	0.0220	0.2440	0.0024	0.0024
010	cheese, American, processed	dairy fat		0.32	1.00	6.4480	2.0634	2.0634	8.9100	2.8512	2.8512	3.7090	1.1869	1.1869	5.0560	1.6179	1.6179
011	cottage cheese, creamed, 4% milkfat	dairy fat		0.04	1.00	4.6980	0.1879	0.1879	2.7490	0.1100	0.1100	7.0640	0.2826	0.2826	6.4310	0.2572	0.2572
012	cheese, Cheddar, (sharp/mild)	dairy fat		0.32	1.00	5.4820	1.7542	1.7542	10.7460	3.4387	3.4387	3.9300	1.2576	1.2576	4.8300	1.5456	1.5456
035	eggs, scrambled with added milk and fat	dairy fat	assume whole milk	0.01	1.00	9.7830	0.0978	0.0978	15.0470	0.1505	0.1505	10.0850	0.1009	0.1009	12.5790	0.1258	0.1258
060	cornbread, southern style, homemade	dairy fat		0.01	1.00	3.8690	0.0387	0.0387	8.8500	0.0885	0.0885	8.3130	0.0831	0.0831	11.9270	0.1193	0.1193
065	muffins (blueberry/plain)	dairy fat		0.03	1.00	0.9470	0.0284	0.0284	0.9450	0.0283	0.0283	1.0140	0.0304	0.0304	0.8380	0.0251	0.0251
068	pancakes made from mix w/addition of egg, milk and oil	dairy fat		0.02	1.00	4.4820	0.0896	0.0896	6.9760	0.1395	0.1395	3.6180	0.0724	0.0724	6.2960	0.1259	0.1259
135	mashed potatoes w/marg. & milk, prepared from instant	dairy fat	milk	0.01	1.00	11.6100	0.1161	0.1161	18.8350	0.1884	0.1884	10.4050	0.1040	0.1040	17.0150	0.1702	0.1702
139	scalloped potatoes, homemade	dairy fat	milk	0.01	1.00	5.1640	0.0516	0.0516	7.4240	0.0742	0.0742	5.3560	0.0536	0.0536	7.6840	0.0768	0.0768
144	pizza, cheese, frozen, commercial, heated	dairy fat	cheese	0.08	1.00	9.2070	0.7366	0.7366	13.5180	1.0814	1.0614	2.0030	0.1602	0.1602	2.2310	0.1785	0.1785
146	macaroni and cheese, prepared from box mix	dairy fat	milk	0.01	1.00	7.4000	0.0740	0.0740	8.6990	0.0870	0.0870	5.1060	0.0511	0.0511	4.4730	0.0447	0.0447
146	macaroni and cheese, prepared from box mix	dairy fat	cheese	0.08	1.00	7.4000	0.5920	0.5920	8.6990	0.6959	0.6959	5.1060	0.4085	0.4085	4.4730	0.3578	0.3578
150	chicken noodle casserole, homemade	dairy fat	milk, cheese	0.02	1.00	2.3550	0.0471	0.0471	5.2490	0.1050	0.1050	2.1530	0.0431	0.0431	1.7760	0.0355	0.0355
151	lasagne, homemade	dairy fat		0.12	1.00	3.0440	0.3653	0.3653	5.1430	0.6172	0.6172	1.5230	0.1828	0.1828	1.9470	0.2336	0.2336
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	dairy fat	milk	0.01	1.00	1.3990	0.0140	0.0140	1.2230	0.0122	0.0122	1.2620	0.0126	0.0126	1.9460	0.0195	0.0195
156	tomato soup, canned, reconstituted with whole milk	dairy fat		0.03	1.00	10.8540	0.3256	0.3256	11.1120	0.3334	0.3334	11.7070	0.3512	0.3512	11.6200	0.3486	0.3486
160	white sauce, medium, homemade	dairy fat	butter, milk	0.13	1.00	0.9790	0.1273	0.1273	1.7100	0.2223	0.2223	0.7340	0.0954	0.0954	1.8370	0.2388	0.2388
164	butter, stick type	dairy fat	regular	1.00	0.84	2.4450	2.4450	2.0538	3.2760	3.2760	2.7518	2.2970	2.2970	1.9295	3.2900	3.2900	2.7636
167	cream, half and half, fluid	dairy fat		0.10	1.00	1.7630	0.1763	0.1763	2.9200	0.2920	0.2920	3.0450	0.3045	0.3045	4.2840	0.4284	0.4284
174	ice cream, chocolate	dairy fat		0.10	1.00	9.3590	0.9359	0.9359	13.4990	1.3499	1.3499	11.3030	1.1303	1.1303	17.7550	1.7755	1.7755
175	pudding, chocolate, instant, made with whole milk	dairy fat		0.03	1.00	2.6720	0.0802	0.0802	3.8430	0.1153	0.1153	4.7000	0.1410	0.1410	5.1830	0.1555	0.1555
176	ice cream sandwich	dairy fat		0.02	1.00	0.6610	0.0132	0.0132	0.5560	0.0111	0.0111	0.3690	0.0074	0.0074	0.5840	0.0117	0.0117
177	ice milk, vanilla	dairy fat		0.05	1.00	1.8990	0.0950	0.0950	2.0470	0.1024	0.1024	2.9220	0.1461	0.1461	2.4560	0.1228	0.1228
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	dairy fat		0.04	1.00	3.3420	0.1337	0.1337	5.9130	0.2365	0.2365	1.9840	0.0794	0.0794	3.4690	0.1388	0.1388
179	yellow cake prep. from mix w/white icing prep. from mix	dairy fat		0.04	1.00	5.5890	0.2236	0.2236	8.9790	0.3592	0.3592	6.8930	0.2757	0.2757	8.2560	0.3302	0.3302
180	coffeecake, (ready-to-eat/frozen)	dairy fat		0.02	1.00	0.7440	0.0149	0.0149	1.3960	0.0279	0.0279	1.1990	0.0240	0.0240	1.4900	0.0298	0.0298
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	dairy fat		0.01	1.00	2.0300	0.0203	0.0203	3.6500	0.0365	0.0365	2.5210	0.0252	0.0252	3.1590	0.0316	0.0316
186	pumpkin pie, frozen, heated	dairy fat		0.02	1.00	3.3030	0.0661	0.0661	5.5980	0.1120	0.1120	4.8070	0.0961	0.0961	5.2000	0.1040	0.1040
188	candy, caramels	dairy fat		0.03	1.00	1.6330	0.0490	0.0490	4.0590	0.1218	0.1218	1.1240	0.0337	0.0337	1.1850	0.0356	0.0356
202	milk-based infant formula w/iron,canned,ready-to serve	dairy fat		0.19	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
203	milk-based infant formula w/o iron,canned,ready-to-serv	dairy fat		0.19	1.00	81.931	15.5669	15.5669	1.9000	0.3610	0.3610	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
204	infant mixed cereal, prepared from dry with whole milk	dairy fat		0.04	1.00	51.842	2.0737	2.0737	0.1470	0.0059	0.0059	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
232	pudding/custard, any flavor, (st./jr.)	dairy fat	heavy cream	0.01	1.00	8.326	0.0833	0.0833	0.0150	0.0002	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		dairy fat-total					39.0454	38.9867		16.6786	16.4844		18.9735	19.7029		30.5399	30.1483
023	veal cutlet, breaded, pan cooked with added fat	egg		0.20	0.25	0.000	0.0000	0.0000	0.2120	0.0424	0.0106	0.4520	0.0904	0.0226	0.3870	0.0774	0.0194
033	shrimp(fresh/frozen),breaded&fried w/add. fat,homemade	egg		0.05	0.25	0.000	0.0000	0.0000	0.1240	0.0062	0.0016	0.7600	0.0380	0.0095	1.1970	0.0599	0.0150
035	eggs, scrambled with added milk and fat	egg		0.76	0.25	6.374	4.8442	1.2111	13.0880	9.9469	2.4867	7.8550	5.9698	1.4925	12.0730	9.1755	2.2939
036	eggs, fried with added fat	egg		0.94	0.25	2.627	2.4694	0.6173	6.1290	5.7613	1.4403	4.5490	4.2761	1.0690	10.0200	9.4188	2.3547
037	eggs, soft boiled	egg	hard cooked, shell removed	1.00	0.24	2.955	2.9550	0.7092	2.8910	2.8910	0.6938	2.4560	2.4560	0.58[illegible]	2.7060	2.7060	0.6494
060	cornbread, southern style, homemade	egg		0.13	0.25	0.877	0.1140	0.0285	3.2590	0.4237	0.1059	4.4320	0.5762	0.1440	6.8760	0.8939	0.2235
065	muffins (blueberry/plain)	egg		0.04	0.25	0.039	0.0016	0.0004	0.6870	0.0275	0.0069	0.9140	0.0366	0.0091	0.7240	0.0290	0.0072
068	pancakes made from mix w/addition of egg, milk and oil	egg		0.35	0.40	1.075	0.3763	0.1505	5.8330	2.0416	0.8166	5.7260	2.0041	0.8016	8.0120	2.[illegible]42	1.1217
069	noodles, egg, enriched, cooked	egg		0.05	0.25	0.791	0.0396	0.0099	1.4090	0.0705	0.0176	1.7470	0.0874	0.0218	3.4270	0.1714	0.0428
111	coleslaw with dressing, homemade	egg	mayonnaise	0.22	0.25	0.001	0.0002	0.0001	0.3470	0.0763	0.0191	1.9620	0.4316	0.1079	1.9830	0.4363	0.1091
142	spaghetti with meat sauce, homemade	egg	noodles	0.03	0.25	4.786	0.1436	0.0359	16.4100	0.4923	0.1231	17.4770	0.5243	0.1311	33.5700	1.0071	0.2518
146	macaroni and cheese, prepared from box mix	egg	noodles	0.05	0.25	3.545	0.1773	0.0443	7.4810	0.3741	0.0935	8.4490	0.4225	0.1056	12.0250	0.6013	0.1503
148	meatloaf, beef, homemade	egg		0.05	0.26	1.193	0.0597	0.0155	3.9830	0.1992	0.0518	6.4960	0.3248	0.0844	10.3690	0.5185	0.1348
149	spaghetti in tomato sauce, canned	egg	noodles	0.17	0.25	2.259	0.3840	0.0960	4.6890	0.7971	0.1993	13.2220	2.2477	0.5619	5.3900	0.9163	0.2291
150	chicken noodle casserole, homemade	egg		0.11	0.25	0.288	0.0317	0.0079	1.2130	0.1334	0.0334	1.7410	0.1915	0.0479	4.1590	0.4575	0.1144
151	lasagne, homemade	egg		0.02	0.26	0.261	0.0052	0.0014	1.1370	0.0227	0.0059	2.5540	0.0511	0.[illegible]33	4.4070	0.0881	0.0229
152	potpie, frozen, commercial, chicken, oven heated	egg		0.14	0.24	0.142	0.0199	0.0048	1.7610	0.2465	0.0592	1.4120	0.1977	0.0174	2.1170	0.2964	0.0711
155	chicken noodle soup, canned, reconstituted with water	egg		0.02	0.26	6.835	0.1367	0.0355	17.8080	0.3562	0.0926	12.6120	0.2522	0.0656	7.0820	0.1416	0.0360
166	mayonnaise, bottled	egg		0.60	0.08	0.046	0.0276	0.0022	0.4980	0.2988	0.0239	1.3850	0.8310	0.0665	1.4240	0.8544	0.0684
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	egg		0.04	0.25	0.170	0.0068	0.0017	2.3260	0.0930	0.0233	6.7310	0.2692	0.0673	8.5340	0.3414	0.0853
179	yellow cake prep. from mix w/white icing prep. from mix	egg		0.04	0.25	0.634	0.0254	0.0063	3.1700	0.1268	0.0317	8.4330	0.3373	0.0843	12.1270	0.4851	0.1213
180	coffeecake, (ready-to-eat/frozen)	egg		0.07	0.25	0.052	0.0036	0.0009	0.2910	0.0204	0.0051	1.2450	0.0872	0.0218	0.9190	0.0643	0.0161
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	egg	white	0.01	0.25	0.516	0.0052	0.0013	2.3650	0.0237	0.0059	4.0180	0.0402	0.0100	6.6590	0.0666	0.0166
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	egg		0.05	0.25	0.119	0.0060	0.0015	0.5470	0.0274	0.0068	2.0850	0.1043	0.0261	5.1720	0.2586	0.0647
183	cookies, chocolate chip	egg		0.06	0.80	2.604	0.1562	0.1250	7.6350	0.4581	0.3665	5.8690	0.3521	0.2817	8.0760	0.4846	0.3876
184	cookies, sandwich type, chocolate w/white cream filling	egg		0.06	0.80	0.844	0.0506	0.0405	3.1210	0.1873	0.1498	1.7950	0.1077	0.0862	3.9590	0.2375	0.1900
186	pumpkin pie, frozen, heated	egg		0.17	0.25	0.440	0.0748	0.0187	1.0020	0.1703	0.0426	3.0270	0.5146	0.1286	3.2390	0.5506	0.1377
214	chicken and noodles, (st./jr.)	egg		0.02	0.25	9.458	0.1892	0.0473	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
215	tomatoes, beef and macaroni, (st./jr.)	egg		0.02	0.25	3.958	0.0792	0.0198	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
232	pudding/custard, any flavor, (st./jr.)	egg	egg yolk	0.01	0.45	8.326	0.0833	0.0375	0.0150	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		egg-total					12.4660	3.2709		25.3146	6.9135		22.8215	6.0974		33.1420	8.9355
003	chocolate milk, fluid, low-fat milk	other	sugar, cocoa, etc.	0.06	0.99	1.725	0.1035	0.1025	10.6730	0.6404	0.6340	38.8010	2.3281	2.3048	61.3540	3.6632	3.6266
007	milkshake, chocolate, fast-food type	other	sugar, syrups, fillers	0.19	0.97	0.451	0.0857	0.0831	1.2860	0.2443	0.2370	5.6250	1.0688	1.0367	9.0970	1.7284	1.6766
009	yogurt, sweetened, strawberry, pre-stirred	other	sugar	0.09	0.99	1.325	0.1193	0.1181	1.7490	0.1574	0.1558	1.0430	0.0939	0.0929	0.6490	0.0584	0.0578
009	yogurt, sweetened, strawberry, pre-stirred	other	fruit	0.04	0.78	1.325	0.0530	0.0413	1.7490	0.0700	0.0546	1.0430	0.0417	0.0325	0.6490	0.0260	0.0202
028	frankfurters, (beef/beef and pork), boiled	other	fillers, sugar	0.02	1.00	2.104	0.0421	0.0421	8.5830	0.1717	0.1717	6.4370	0.1287	0.1287	8.7610	0.1752	0.1752
033	shrimp(fresh/frozen),breaded&fried w/add. fat,homemade	other	sugar	0.03	0.99	0.000	0.0000	0.0000	0.1240	0.0037	0.0037	0.7600	0.0228	0.0226	1.1970	0.0359	0.0356
047	peanut butter, creamy, commercial in jar	other	sugar, corn syrup	0.31	1.00	0.496	0.1538	0.1538	2.9110	0.9024	0.9024	2.1700	0.6727	0.6727	4.6830	1.4517	1.4517
049	pecans, packaged, unsalted	other		1.00	0.97	0.006	0.0060	0.0058	0.2470	0.2470	0.2396	0.4100	0.4100	0.3977	0.5050	0.5050	0.4899
058	whitebread, enriched	other	sugar, corn syrup	0.26	0.73	6.303	1.6388	1.1963	26.8370	6.9776	5.0937	38.7510	10.0753	7.3549	55.6700	14.4763	10.5677
059	rolls, white, soft, enriched	other		0.23	0.99	0.770	0.1771	0.1753	4.1040	0.9439	0.9345	13.2400	3.0452	3.0147	21.4950	4.9439	4.8944
060	cornbread, southern style, homemade	other	sugar	0.06	0.99	0.877	0.0526	0.0521	3.2590	0.1955	0.1936	4.4320	0.2659	0.2633	6.8760	0.4126	0.4084
061	biscuits,baking powder,enriched,refrigerated type,baked	other	sugar, corn syrup	0.24	0.73	0.620	0.1488	0.1086	2.5820	0.6197	0.4524	3.6600	0.8803	0.6426	4.8560	1.1654	0.8500

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
203	milk-based infant formula w/o iron,canned,ready-to-serv	dairy fat		0.19	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
209	infant mixed cereal, prepared from dry with whole milk	dairy fat		0.04	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
232	pudding/custard, any flavor, (st./jr.)	dairy fat	heavy cream	0.01	1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		dairy fat-total					15.3339	15.1627		23.3098	22.7086		12.6653	12.2909		17.2328	16.7204
023	veal cutlet, breaded, pan cooked with added fat	egg		0.20	0.25	1.3450	0.2690	0.0673	0.8390	0.1678	0.0420	0.9516	0.1902	0.0476	1.3510	0.2702	0.0676
033	shrimp(fresh/frozen),breaded&fried w/add. fat,homemade	egg		0.05	0.25	2.6550	0.1328	0.0332	3.4720	0.1736	0.0434	1.9740	0.0987	0.0247	1.8440	0.0922	0.0231
035	eggs, scrambled with added milk and fat	egg		0.76	0.25	9.7830	7.4351	1.8588	15.0470	11.4357	2.8589	10.0850	7.6646	1.9162	12.5790	9.5600	2.3900
036	eggs, fried with added fat	egg		0.94	0.25	6.0360	5.6738	1.4185	11.4990	10.8091	2.7023	6.5660	6.1720	1.5430	16.3100	15.3194	3.8299
037	eggs, soft boiled	egg	hard cooked, shell removed	1.00	0.24	4.7510	4.7510	1.1402	4.4080	4.4080	1.0579	7.0170	7.0170	1.6841	9.3510	9.3510	2.2442
060	cornbread, southern style, homemade	egg		0.13	0.25	3.8690	0.5030	0.1257	8.8500	1.1505	0.2876	8.3130	1.0807	0.2702	11.9270	1.5505	0.3876
063	muffins (blueberry/plain)	egg		0.04	0.25	0.9470	0.0379	0.0095	0.9450	0.0378	0.0095	1.0140	0.0406	0.0101	0.8380	0.0335	0.0084
068	pancakes made from mix w/addition of egg, milk and oil	egg		0.35	0.40	4.4820	1.5687	0.6275	6.9760	2.4416	0.9766	3.6180	1.2663	0.5065	6.2960	2.2036	0.8814
069	noodles, egg, enriched, cooked	egg		0.05	0.25	1.8590	0.0930	0.0232	2.4990	0.1250	0.0312	1.2100	0.0605	0.0151	2.3260	0.1163	0.0291
111	coleslaw with dressing, homemade	egg	mayonnaise	0.22	0.25	2.4220	0.5328	0.1332	2.8870	0.6351	0.1588	2.6740	0.5883	0.1471	3.2530	0.7157	0.1789
142	spaghetti with meat sauce, homemade	egg	noodles	0.03	0.25	15.5010	0.4650	0.1163	23.9170	0.7175	0.1794	8.9560	0.2687	0.0672	11.0850	0.3326	0.0831
146	macaroni and cheese, prepared from box mix	egg	noodles	0.05	0.25	7.4000	0.3700	0.0925	8.6990	0.4350	0.1087	5.1060	0.2553	0.0638	4.4730	0.2237	0.0559
148	meatloaf, beef, homemade	egg		0.05	0.26	5.5950	0.2798	0.0727	12.2880	0.6144	0.1597	4.3420	0.2171	0.0564	7.0660	0.3533	0.0919
149	spaghetti in tomato sauce, canned	egg	noodles	0.17	0.25	4.1410	0.7040	0.1760	4.2160	0.7167	0.1792	1.8750	0.3188	0.0797	3.2770	0.5571	0.1393
150	chicken noodle casserole, homemade	egg		0.11	0.25	2.3550	0.2591	0.0648	5.2490	0.5774	0.1443	2.1530	0.2368	0.0592	1.7760	0.1954	0.0488
151	lasagna, homemade	egg		0.02	0.26	3.0440	0.0609	0.0156	5.1430	0.1029	0.0267	1.5230	0.0305	0.0079	1.9470	0.0389	0.0101
152	potpie, frozen, commercial, chicken, oven heated	egg		0.14	0.24	1.3440	0.1882	0.0452	2.0880	0.2923	0.0702	1.4940	0.2092	0.0502	1.3920	0.1949	0.0468
155	chicken noodle soup, canned, reconstituted with water	egg		0.02	0.26	7.0920	0.1418	0.0369	7.5110	0.1502	0.0391	8.2750	0.1655	0.0430	14.2020	0.2840	0.0739
166	mayonnaise, bottled	egg		0.60	0.08	1.3140	0.7884	0.0631	2.7290	1.6374	0.1310	1.1110	0.6666	0.0533	1.5550	0.9330	0.0746
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	egg		0.04	0.25	3.3420	0.1337	0.0334	5.9130	0.2365	0.0591	1.9840	0.0794	0.0198	3.4690	0.1388	0.0347
179	yellow cake prep. from mix w/white icing prep. from mix	egg		0.04	0.25	5.5890	0.2236	0.0559	8.9790	0.3592	0.0898	6.8930	0.2757	0.0689	8.2560	0.3302	0.0826
180	coffeecake, (ready-to-eat/frozen)	egg		0.07	0.25	0.7440	0.0521	0.0130	1.3960	0.0977	0.0244	1.1990	0.0839	0.0210	1.4900	0.1043	0.0261
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	egg	white	0.01	0.25	3.6910	0.0369	0.0092	5.6830	0.0568	0.0142	2.3070	0.0231	0.0058	4.7270	0.0473	0.0118
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	egg		0.05	0.25	2.0300	0.1015	0.0254	3.6500	0.1825	0.0456	2.5210	0.1261	0.0315	3.1590	0.1580	0.0395
183	cookies, chocolate chip	egg		0.06	0.80	3.7510	0.2251	0.1800	4.7230	0.2834	0.2267	3.0840	0.1850	0.1480	4.5760	0.2746	0.2196
184	cookies, sandwich type, chocolate w/white cream filling	egg		0.06	0.80	1.6480	0.0989	0.0791	2.7150	0.1629	0.1303	1.0520	0.0631	0.0505	2.4320	0.1459	0.1167
186	pumpkin pie, frozen, heated	egg		0.17	0.25	3.3030	0.5615	0.1404	5.5980	0.9517	0.2379	4.8070	0.8172	0.2043	5.2000	0.8840	0.2210
214	chicken and noodles, (st./jr.)	egg		0.02	0.25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
215	tomatoes, beef and macaroni, (st./jr.)	egg		0.02	0.25	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
232	pudding/custard, any flavor, (st./jr.)	egg	egg yolk	0.01	0.45	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		egg-total					25.6873	6.6567		38.9586	10.0347		28.2007	7.1952		44.6082	11.4666
003	chocolate milk, fluid, low-fat milk	other	sugar, cocoa, etc.	0.06	0.99	10.3840	0.6230	0.6168	14.3360	0.8602	0.8516	3.7360	0.2242	0.2219	5.0710	0.3043	0.3012
067	milkshake, chocolate, fast-food type	other	sugar, syrups, fillers	0.19	0.97	3.1250	0.5938	0.5759	4.3490	0.8263	0.8015	0.3280	0.0623	0.0605	1.0830	0.2058	0.1996
069	yogurt, sweetened, strawberry, pre-stirred	other	sugar	0.09	0.99	3.0960	0.2786	0.2759	2.9320	0.2639	0.2612	2.2030	0.1983	0.1963	0.2440	0.0220	0.0217
009	yogurt, sweetened, strawberry, pre-stirred	other	fruit	0.04	0.78	3.0960	0.1238	0.0966	2.9320	0.1173	0.0915	2.2030	0.0881	0.0687	0.2440	0.0098	0.0076
028	frankfurters, (beef/beef and pork), boiled	other	fillers, sugar	0.02	1.00	5.2320	0.1046	0.1046	8.5910	0.1718	0.1718	3.7530	0.0751	0.0751	5.3520	0.1070	0.1070
033	shrimp(fresh/frozen),breaded&fried w/add. fat,homemade	other	sugar	0.03	0.99	2.6550	0.0796	0.0789	3.4720	0.1042	0.1031	1.9740	0.0592	0.0586	1.8440	0.0553	0.0548
047	peanut butter, creamy, commercial in jar	other	sugar, corn syrup	0.31	1.00	1.2140	0.3763	0.3763	2.5290	0.7840	0.7840	1.1940	0.3701	0.3701	1.8230	0.5651	0.5651
049	pecans, packaged, unsalted	other		1.00	0.97	0.9640	0.9640	0.9351	0.7810	0.7810	0.7576	0.5000	0.5000	0.4850	0.9550	0.9550	0.9263
058	whitebread, enriched	other	sugar, corn syrup	0.26	0.73	34.4240	8.9502	6.5337	36.7200	9.5472	6.9695	34.9880	9.0969	6.6407	50.8730	13.2270	9.6557
059	rolls, white, soft, enriched	other		0.23	0.99	10.0550	2.3127	2.2895	20.2870	4.6660	4.6193	6.0290	1.3867	1.3728	9.0500	2.0815	2.0607
060	cornbread, southern style, homemade	other	sugar	0.06	0.99	3.8690	0.2321	0.2298	8.8500	0.5310	0.5257	8.3130	0.4988	0.4938	11.9270	0.7156	0.7085
061	biscuits,baking powder,enriched,refrigerated type,baked	other	sugar, corn syrup	0.24	0.73	3.0630	0.7351	0.5366	5.0310	1.2074	0.8814	4.0800	0.9792	0.7148	7.8060	1.8734	1.3676

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
062	whole wheat bread	other	sugar, syrups	0.30	0.99	0.653	0.1959	0.1939	2.7060	0.8118	0.8037	2.1560	0.6468	0.6403	3.3770	1.0131	1.0030
064	rye bread	other	sugar, corn syrup	0.23	0.73	0.082	0.0189	0.0138	0.6870	0.1580	0.1153	0.9140	0.2102	0.1535	0.7240	0.1665	0.1216
065	muffins (blueberry/plain)	other	sugar	0.13	0.99	0.039	0.0051	0.0050	0.6870	0.0893	0.0884	0.9140	0.1188	0.1176	0.7240	0.0941	0.0932
065	muffins (blueberry/plain)	other	blueberry	0.08	0.15	0.039	0.0031	0.0005	0.6870	0.0550	0.0082	0.9140	0.0731	0.0110	0.7240	0.0579	0.0087
072	fruit flavored, presweetened cereal	other	sugar,salt,iron,vitamins	0.19	0.98	0.166	0.0315	0.0309	2.7390	0.5204	0.5100	1.4610	0.2776	0.2720	3.3300	0.6327	0.6200
074	Raisin Bran cereal	other	sugar	0.21	0.99	0.047	0.0099	0.0098	1.1580	0.2432	0.2407	1.0600	0.2226	0.2204	2.9710	0.6239	0.6177
074	Raisin Bran cereal	other	raisins	0.22	0.82	0.047	0.0103	0.0085	1.1580	0.2548	0.2089	1.0600	0.2332	0.1912	2.9710	0.6536	0.5360
075	crisped rice cereal	other	sugar	0.29	0.99	0.418	0.1212	0.1200	1.7490	0.5072	0.5021	0.9910	0.2874	0.2845	2.1960	0.6368	0.6305
076	granola, with raisins	other	raisins	0.26	0.82	0.204	0.0530	0.0435	0.2850	0.0741	0.0608	0.2160	0.0562	0.0461	0.2940	0.0764	0.0627
076	granola, with raisins	other	sugar	0.13	0.99	0.204	0.0265	0.0263	0.2850	0.0371	0.0367	0.2160	0.0281	0.0278	0.2940	0.0382	0.0378
077	oat ring. unsweetened cereal	other	sugar	0.05	0.99	0.428	0.0214	0.0212	2.0010	0.1001	0.0990	1.2820	0.0641	0.0635	3.9890	0.1995	0.1975
078	apple, red with peel, raw	other	fruit	1.00	0.16	0.947	0.9470	0.1515	16.7150	16.7150	2.6744	12.3630	12.3630	1.9781	18.6800	18.6800	2.9888
079	orange, raw, (navel/Valencia)	other	fruit	1.00	0.14	1.642	1.6420	0.2299	7.3410	7.3410	1.0277	7.0820	7.0820	0.9915	9.6380	9.6380	1.3493
080	banana, raw	other	fruit	1.00	0.24	5.781	5.7810	1.3874	10.8580	10.8580	2.6059	5.1950	5.1950	1.2468	8.1010	8.1010	1.9442
081	watermelon, raw	other	fruit	1.00	0.07	0.252	0.2520	0.0176	2.4690	2.4690	0.1728	5.9190	5.9190	0.4143	3.1560	3.1560	0.2209
082	peach, canned in heavy syrup	other	sugar, syrup, etc.	0.56	0.27	11.666	6.5330	1.7639	4.5720	2.5603	0.6913	3.4360	1.9242	0.5195	4.4180	2.4741	0.6680
082	peach, canned in heavy syrup	other	fruit	0.44	0.09	11.666	5.1330	0.4620	4.5720	2.0117	0.1811	3.4360	1.5118	0.1361	4.4180	1.9439	0.1750
083	peach, raw	other	fruit	1.00	0.11	1.558	1.5580	0.1714	2.9640	2.9640	0.3260	3.9350	3.9350	0.4329	2.2680	2.2680	0.2495
084	applesauce, canned, sweetened	other	fruit	0.44	0.11	9.057	3.9851	0.4384	5.6870	2.5023	0.2753	3.7010	1.6284	0.1791	4.8700	2.1428	0.2357
084	applesauce, canned, sweetened	other	sugar	0.56	0.00	9.057	5.0719	0.0000	5.6870	3.1847	0.0000	3.7010	2.0726	0.0000	4.8700	2.7272	0.0000
085	pear, raw	other	fruit	1.00	0.17	1.111	1.1110	0.1889	2.4310	2.4310	0.4133	1.4980	1.4980	0.2547	3.0100	3.0100	0.5117
086	strawberries, raw	other	fruit	1.00	0.10	0.498	0.4980	0.0498	1.2090	1.2090	0.1209	1.5530	1.5530	0.1553	1.2550	1.2550	0.1255
087	fruit cocktail, canned in heavy syrup	other	sugar, syrup, etc.	0.56	0.27	0.390	0.2184	0.0590	1.9600	1.0976	0.2964	2.7920	1.5635	0.4222	3.7240	2.0854	0.5631
087	fruit cocktail, canned in heavy syrup	other	fruit	0.44	0.09	0.390	0.1716	0.0154	1.9600	0.8624	0.0776	2.7920	1.2285	0.1106	3.7240	1.6386	0.1475
088	grapes (purple/green), raw	other	fruit	1.00	0.19	0.030	0.0300	0.0057	1.6160	1.6160	0.3070	1.1230	1.1230	0.2134	1.7130	1.7130	0.3255
089	cantaloupe, raw	other	fruit with rind	1.00	0.09	0.623	0.6230	0.0561	0.7010	0.7010	0.0631	3.3440	3.3440	0.3010	1.7780	1.7780	0.1600
090	pear, canned in heavy syrup	other	sugar, syrup, etc.	0.56	0.27	3.875	2.1700	0.5859	0.9130	0.5113	0.1380	0.7830	0.4385	0.1184	2.5890	1.4498	0.3915
090	pear, canned in heavy syrup	other	fruit	0.44	0.09	3.875	1.7050	0.1535	0.9130	0.4017	0.0362	0.7830	0.3445	0.0310	2.5890	1.1392	0.1025
091	plums, pruple, raw	other	fruit, Japanese & hybrid	1.00	0.13	0.311	0.3110	0.0404	0.5640	0.5640	0.0733	1.1930	1.1930	0.1551	0.5420	0.5420	0.0705
092	grapefruit, raw	other	fruit	1.00	0.11	0.000	0.0000	0.0000	0.8430	0.8430	0.0927	2.9770	2.9770	0.3275	1.4740	1.4740	0.1621
093	pineapple, canned in juice pack	other	fruit, includes fruit pack juices	1.00	0.15	0.302	0.3020	0.0453	0.7240	0.7240	0.1086	0.9140	0.9140	0.1371	0.6940	0.6940	0.1041
094	cherries, sweet, raw	other	fruit	1.00	0.20	0.190	0.1900	0.0380	0.2350	0.2350	0.0470	0.2250	0.2250	0.0450	0.4740	0.4740	0.0948
095	raisins, dried	other	fruit	1.00	0.82	0.167	0.1670	0.1369	1.1580	1.1580	0.9496	0.2910	0.2910	0.2386	0.3220	0.3220	0.2640
096	prunes, dried, uncooked	other	fruit	1.00	0.72	0.064	0.0640	0.0461	0.0940	0.0940	0.0677	0.0690	0.0690	0.0497	0.0170	0.0170	0.0122
098	orange juice, frozen, reconstituted	other	fruit, 3 parts water	1.00	0.13	18.115	18.1150	2.3549	59.3700	59.3700	7.7181	42.1210	42.1210	5.4757	60.7340	60.7340	7.8954
099	apple juice, canned, unsweetened	other	fruit	1.00	0.12	17.094	17.0940	2.0513	17.5940	17.5940	2.1113	5.3780	5.3780	0.6454	4.0900	4.0900	0.4908
100	grapefruit juice, frozen, reconstituted	other	fruit, 3 parts water	1.00	0.11	0.769	0.7690	0.0846	1.1190	1.1190	0.1231	2.0670	2.0670	0.2274	3.0670	3.0670	0.3374
101	grape juice, canned	other	fruit	1.00	0.17	2.885	2.8850	0.4905	8.7840	8.7840	1.4933	2.9250	2.9250	0.4973	3.9620	3.9620	0.6735
102	pineapple juice, canned	other	fruit, unsweetened	1.00	0.14	1.037	1.0370	0.1452	2.3080	2.3080	0.3231	0.3820	0.3820	0.0535	1.2830	1.2830	0.1796
103	prune juice, bottled	other	fruit	1.00	0.20	0.000	0.0000	0.0000	0.2960	0.2960	0.0592	0.0320	0.0320	0.0064	0.0780	0.0780	0.0156
104	orange drink with added vitamin C, canned	other	fruit, sugar, water	1.00	0.10	9.447	9.4470	0.9447	24.9540	24.9540	2.4954	19.0140	19.0140	1.9014	20.4840	20.4840	2.0484
105	lemonade, frozen, reconstituted	other	fruit, 4 1/3 parts water	1.00	0.11	0.207	0.2070	0.0228	4.6410	4.6410	0.5105	9.2030	9.2030	1.0123	11.5470	11.5470	1.2702
111	coleslaw with dressing, homemade	other	sugar	0.18	0.99	0.001	0.0002	0.0002	0.3470	0.0625	0.0618	1.9620	0.3532	0.3496	1.9830	0.3569	0.3534
111	coleslaw with dressing, homemade	other	vinegar	0.02	0.04	0.001	0.0000	0.0000	0.3470	0.0069	0.0003	1.9620	0.0392	0.0016	1.9830	0.0397	0.0016
141	sweet potato, candied, homemade	other	sugar	0.31	0.99	0.095	0.0295	0.0292	0.3550	0.1101	0.1089	0.3220	0.0998	0.0988	0.9470	0.2936	0.2906
142	spaghetti with meat sauce, homemade	other	sugar	0.03	0.99	4.786	0.1436	0.1421	16.4100	0.4923	0.4874	17.4770	0.5243	0.5191	33.5700	1.0071	0.9970
143	beef and vegetable stew, homemade	other	seasoning	0.05	1.00	2.838	0.1419	0.1419	5.7980	0.2899	0.2899	8.8880	0.4444	0.4444	10.8960	0.5448	0.5448
144	pizza, cheese, frozen, commercial, heated	other	sugar	0.40	0.99	0.484	0.1936	0.1917	3.1980	1.2792	1.2664	12.4450	4.9780	4.9282	39.9780	15.9912	15.8313
153	pork chow mein, homemade	other	celery, water chestnuts, sprouts	0.10	0.04	0.321	0.0321	0.0013	0.8090	0.0809	0.0032	2.0730	0.2073	0.0083	3.1190	0.3119	0.0125

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
062	whole wheat bread	other	sugar, syrups	0.30	0.99	4.1780	1.2534	1.2409	7.7820	2.3346	2.3113	5.4900	1.6470	1.6305	6.5870	1.9761	1.9563
064	rye bread	other	sugar, corn syrup	0.23	0.73	0.9470	0.2178	0.1590	0.9450	0.2174	0.1587	1.0140	0.2332	0.1703	0.8380	0.1927	0.1407
065	muffins (blueberry/plain)	other	sugar	0.13	0.99	0.9470	0.1231	0.1219	0.9450	0.1229	0.1216	1.0140	0.1318	0.1305	0.8380	0.1089	0.1079
065	muffins (blueberry/plain)	other	blueberry	0.08	0.15	0.9470	0.0758	0.0114	0.9450	0.0756	0.0113	1.0140	0.0811	0.0122	0.8380	0.0670	0.0101
072	fruit flavored, presweetened cereal	other	sugar,salt,iron,..tamins	0.19	0.98	0.2600	0.0494	0.0484	1.9440	0.3694	0.3620	0.0670	0.0127	0.0125	0.0680	0.0129	0.0127
074	Raisin Bran cereal	other	sugar	0.21	0.99	1.2310	0.2585	0.2559	1.3110	0.2753	0.2726	2.3010	0.4832	0.4784	4.3480	0.9131	0.9039
074	Raisin Bran cereal	other	raisins	0.22	0.82	1.2310	0.2708	0.2221	1.3110	0.2884	0.2365	2.3010	0.5062	0.4151	4.3480	0.9566	0.7844
075	crisped rice cereal	other	sugar	0.29	0.99	0.7760	0.2250	0.2228	0.9410	0.2729	0.2702	1.0540	0.3057	0.3026	0.8580	0.2488	0.2463
076	granola, with raisins	other	raisins	0.26	0.82	0.5870	0.1526	0.1251	1.6410	0.4267	0.3499	0.7530	0.1958	0.1605	0.4600	0.1196	0.0981
076	granola, with raisins	other	sugar	0.13	0.99	0.5870	0.0763	0.0755	1.6410	0.2133	0.2112	0.7530	0.0979	0.0969	0.4600	0.0598	0.0592
077	oat ring. unsweetened cereal	other	sugar	0.05	0.99	0.4670	0.0234	0.0231	0.9280	0.0464	0.0459	0.3450	0.0172	0.0171	0.2910	0.0146	0.0144
078	apple, red with peel, raw	other	fruit	1.00	0.16	13.9850	13.9850	2.2376	12.1150	12.1150	1.9384	15.7500	15.7500	2.5200	15.5160	15.5160	2.4826
079	orange, raw, (navel/Valencia)	other	fruit	1.00	0.14	7.9740	7.9740	1.1164	9.2640	9.2640	1.2970	8.8550	8.8550	1.2397	9.4540	9.4540	1.3236
080	banana, raw	other	fruit	1.00	0.24	5.8490	5.8490	1.4038	6.7160	6.7160	1.6118	12.7190	12.7190	3.0526	13.5100	13.5100	3.2424
081	watermelon, raw	other	fruit	1.00	0.07	3.8670	3.8670	0.2707	3.5300	3.5300	0.2471	7.2650	7.2650	0.5086	4.7570	4.7570	0.3330
092	peach, canned in heavy syrup	other	sugar, syrup, etc.	0.56	0.27	2.4020	1.3451	0.3632	4.7570	2.6639	0.7193	6.6790	3.7402	1.0099	8.4580	4.7365	1.2788
082	peach, canned in heavy syrup	other	fruit	0.44	0.09	2.4020	1.0569	0.0951	4.7570	2.0931	0.1884	6.6790	2.9388	0.2645	8.4580	3.7215	0.3349
083	peach, raw	other	fruit	1.00	0.11	3.8340	3.8340	0.4217	3.4940	3.4940	0.3843	6.9240	6.9240	0.7616	7.0530	7.0530	0.7758
084	applesauce, canned, sweetened	other	fruit	0.44	0.11	2.4410	1.0740	0.1181	2.5950	1.1418	0.1256	4.7950	2.1098	0.2321	5.4900	2.4156	0.2657
084	applesauce, canned, sweetened	other	sugar	0.56	0.00	2.4410	1.3670	0.0000	2.5950	1.4532	0.0000	4.7950	2.6852	0.0000	5.4900	3.0744	0.0000
085	pear, raw	other	fruit	1.00	0.17	2.1400	2.1400	0.3638	2.3830	2.3830	0.4051	3.7800	3.7800	0.6426	3.0390	3.0390	0.5166
086	strawberries, raw	other	fruit	1.00	0.10	1.8820	1.8820	0.1882	1.2310	1.2310	0.1231	4.3890	4.3890	0.4389	4.7390	4.7390	0.4739
087	fruit cocktail, canned in heavy syrup	other	sugar, syrup, etc.	0.56	0.27	3.9170	2.1935	0.5923	3.0200	1.6912	0.4566	5.5090	[illegible]	0.8330	4.9420	2.7675	0.7472
087	fruit cocktail, canned in heavy syrup	other	fruit	0.44	0.09	3.9170	1.7235	0.1551	3.0200	1.3288	0.1196	5.5090	2.4240	0.2182	4.9420	2.1745	0.1957
088	grapes (purple/green), raw	other	fruit	1.00	0.19	1.1960	1.1960	0.2272	0.6450	0.6450	0.1226	1.0570	1.0570	0.2008	1.3170	1.3170	0.2502
089	cantaloupe, raw	other	fruit with rind	1.00	0.09	3.1380	3.1380	0.2824	2.8220	2.8220	0.2540	8.5100	8.5100	0.7659	6.9010	6.9010	0.6211
090	pear, canned in heavy syrup	other	sugar, syrup, etc.	0.56	0.27	0.7940	0.4446	0.1201	1.4710	0.8238	0.2224	2.7430	1.5361	0.4147	3.1140	1.7438	0.4708
090	pear, canned in heavy syrup	other	fruit	0.44	0.09	0.7940	0.3494	0.0314	1.4710	0.6472	0.0583	2.7430	1.2069	0.1086	3.1140	1.3702	0.1233
091	plums, pruple, raw	other	fruit, Japanese & hybrid	1.00	0.13	0.7340	0.7340	0.0954	0.9450	0.9450	0.1229	1.8510	1.8510	0.2406	1.6660	1.6660	0.2166
092	grapefruit, raw	other	fruit	1.00	0.11	6.2010	6.2010	0.6821	4.2770	4.2770	0.4705	17.7660	17.7660	1.9543	10.2090	10.2090	1.1230
093	pineapple, canned in juice pack	other	fruit, includes fruit pack juices	1.00	0.15	1.3960	1.3960	0.2094	0.8850	0.8850	0.1328	2.2340	2.2340	0.3351	1.5980	1.5980	0.2397
094	cherries, sweet, raw	other	fruit	1.00	0.20	0.5920	0.5920	0.1184	0.4760	0.4760	0.0952	0.7850	0.7850	0.1570	0.7540	0.7540	0.1508
095	raisins, dried	other	fruit	1.00	0.82	0.2570	0.2570	0.2107	0.3590	0.3590	0.2944	0.4550	0.4550	0.3731	0.4100	0.4100	0.3362
096	prunes, dried, uncooked	other	fruit	1.00	0.72	0.0910	0.0910	0.0655	0.1060	0.1060	0.0763	1.0140	1.0140	0.7301	0.9040	0.9040	0.6509
098	orange juice, frozen, reconstituted	other	fruit, 3 parts water	1.00	0.13	50.5310	50.5310	6.5690	58.9540	58.9540	7.6640	54.0060	54.0060	7.0208	46.2140	46.2140	6.0078
099	apple juice, canned, unsweetened	other	fruit	1.00	0.12	6.4540	6.4540	0.7745	3.2800	3.2800	0.3936	3.2630	3.2630	0.3916	2.3350	2.3350	0.2802
100	grapefruit juice, frozen, reconstituted	other	fruit, 3 parts water	1.00	0.11	6.7760	6.7760	0.7454	3.5040	3.5040	0.3854	8.9020	8.9020	0.9792	7.4950	7.4950	0.8245
101	grape juice, canned	other	fruit	1.00	0.17	4.5470	4.5470	0.7730	4.4190	4.4190	0.7512	3.9430	3.9430	0.6703	2.6090	2.6090	0.4435
102	pineapple juice, canned	other	fruit, unsweetened	1.00	0.14	1.2360	1.2360	0.1730	1.8020	1.8020	0.2523	1.1740	1.1740	0.1644	1.0900	1.0900	0.1526
103	prune juice, bottled	other	fruit	1.00	0.20	0.1640	0.1640	0.0328	0.1850	0.1850	0.0370	2.2580	2.2580	0.4516	1.4220	1.4220	0.2844
104	orange drink with added vitamin C, canned	other	fruit, sugar, water	1.00	0.10	15.8260	15.8260	1.5826	17.0460	17.0460	1.7046	8.3350	8.3350	0.8335	5.9680	5.9680	0.5968
105	lemonade, frozen, reconstituted	other	fruit, 4 1/3 parts water	1.00	0.11	8.8900	8.8900	0.9779	10.7070	10.7070	1.1778	6.9830	6.9830	0.7681	5.4310	5.4310	0.5974
111	coleslaw with dressing, homemade	other	sugar	0.18	0.99	2.4220	0.4360	0.4316	2.8870	0.5197	0.5145	2.6740	0.4813	0.4765	3.2530	0.5855	0.5797
111	coleslaw with dressing, homemade	other	vinegar	0.02	0.04	2.4220	0.0484	0.0019	2.8870	0.0577	0.0023	2.6740	0.0535	0.0021	3.2530	0.0651	0.0026
141	sweet potato, candied, homemade	other	sugar	0.31	0.99	0.5620	0.1742	0.1725	1.0080	0.3125	0.3094	0.6090	0.1888	0.1869	0.5930	0.1838	0.1820
142	spaghetti with meat sauce, homemade	other	sugar	0.03	0.99	15.5010	0.4650	0.4604	23.9170	0.7175	0.7103	8.9560	0.2687	0.2660	11.0850	0.3326	0.3292
143	beef and vegetable stew, homemade	other	seasoning	0.05	1.00	8.0740	0.4037	0.4037	11.3150	0.5658	0.5658	10.9010	0.5451	0.5451	14.5170	0.7259	0.7259
144	pizza, cheese, frozen, commercial, heated	other	sugar	0.40	0.99	9.2070	3.6828	3.6460	13.5180	5.4072	5.3531	2.0030	0.8012	0.7932	2.2310	0.8924	0.8835
153	pork chow mein, homemade	other	celery, water chestnuts, sprouts	0.10	0.04	3.8240	0.3824	0.0153	4.5130	0.4513	0.0181	2.9200	0.2920	0.0117	2.9040	0.2904	0.0116

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	other	sugar	0.02	0.99	0.065	0.0013	0.0013	1.6920	0.0338	0.0335	1.3290	0.0266	0.0263	0.6830	0.0177	0.0175
158	beef bouillon, canned, reconstituted with water	other	sugar	0.25	0.99	0.274	0.0685	0.0678	1.0490	0.2623	0.2596	0.7770	0.1943	0.1923	1.1820	0.2955	0.2925
159	gravy, brown, from mix	other	sugar	0.01	0.99	1.891	0.0189	0.0187	3.5130	0.0351	0.0348	6.1630	0.0616	0.0610	7.3600	0.0736	0.0729
168	cream substitute, powdered	other	vegetable fat & sweetener	1.00	0.10	0.280	0.2800	0.0280	0.2640	0.2640	0.0264	0.1830	0.1830	0.0183	0.1280	0.1280	0.0128
169	sugar, white, granulated	other		1.00	0.99	0.913	0.9130	0.9039	3.1980	3.1980	3.1660	4.4420	4.4420	4.3976	4.7880	4.7880	4.7401
170	syrup, pancake, bottled	other	sugar	0.51	0.99	0.561	0.2861	0.2832	2.4540	1.2515	1.2390	3.6300	1.8513	1.8328	5.9630	3.0411	3.0107
171	jelly, grape, bottled	other	fruit	0.25	0.37	0.556	0.1390	0.0514	2.5630	0.6408	0.2371	2.8660	0.7165	0.2651	4.6480	1.1620	0.4299
171	jelly, grape, bottled	other	sugar	0.75	0.99	0.556	0.4170	0.4128	2.5630	1.9223	1.9030	2.8660	2.1495	2.1280	4.6480	3.4860	3.4511
172	honey, bottled	other		1.00	0.83	0.334	0.3340	0.2772	0.3470	0.3470	0.2880	0.6180	0.6180	0.5129	0.5440	0.5440	0.4515
173	catsup, bottled	other	sugar	0.25	0.99	0.102	0.0255	0.0252	1.3110	0.3278	0.3245	2.3670	0.5918	0.5858	4.4720	1.1180	1.1068
173	catsup, bottled	other	vinegar	0.30	0.01	0.102	0.0306	0.0003	1.3110	0.3933	0.0039	2.3670	0.7101	0.0071	4.4720	1.3416	0.0134
174	ice cream, chocolate	other	sugar	0.15	0.99	1.490	0.2235	0.2213	9.5790	1.4369	1.4225	15.6850	2.3528	2.3292	23.0440	3.4566	3.4220
175	pudding, chocolate, instant, made with whole milk	other	sugar	0.81	0.99	1.280	1.0368	1.0264	3.4870	2.8245	2.7962	3.4120	2.7637	2.7361	6.5920	5.3395	5.2861
176	ice cream sandwich	other	sugar	0.15	0.99	0.054	0.0081	0.0080	1.1640	0.1746	0.1729	1.9210	0.2882	0.2853	2.5240	0.3786	0.3748
177	ice milk, vanilla	other	sugar	0.15	0.99	0.116	0.0174	0.0172	1.7240	0.2586	0.2560	2.8690	0.4304	0.4260	5.5750	0.8363	0.8279
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	other	sugar, cocoa	0.44	0.99	0.170	0.0748	0.0741	2.3260	1.0234	1.0132	6.7310	2.9616	2.9320	8.5340	3.7550	3.7174
179	yellow cake prep. from mix w/white icing prep. from mix	other	sugar	0.44	0.99	0.634	0.2790	0.2762	3.1700	1.3948	1.3809	8.4330	3.7105	3.6734	12.1270	5.3359	5.2825
180	coffeecake, (ready-to-eat/frozen)	other	sugar, etc.	0.22	0.99	0.052	0.0114	0.0113	0.2910	0.0640	0.0634	1.2450	0.2739	0.2712	0.9190	0.2022	0.2002
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	other	sugar	0.25	0.99	0.516	0.1290	0.1277	2.3650	0.5913	0.5853	4.0180	1.0045	0.9945	6.6590	1.6648	1.6481
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	other	sugar	0.07	0.99	0.119	0.0083	0.0082	0.5470	0.0383	0.0379	2.0850	0.1460	0.1445	5.1720	0.3620	0.3584
183	cookies, chocolate chip	other	sugar	0.26	0.99	2.604	0.6770	0.6703	7.6350	1.9851	1.9652	5.8690	1.5259	1.5107	8.0760	2.0998	2.0788
183	cookies, chocolate chip	other	chocolate chips	0.07	0.98	2.604	0.1823	0.1786	7.6350	0.5345	0.5238	5.9690	0.4178	0.4095	8.0760	0.5653	0.5540
184	cookies, sandwich type, chocolate w/white cream filling	other	sugar	0.36	0.99	0.844	0.3038	0.3008	3.1210	1.1236	1.1123	1.7950	0.6462	0.6397	3.9590	1.4252	1.4110
185	apple pie, frozen, heated	other	sugar	0.28	0.99	0.224	0.0627	0.0621	1.6930	0.4740	0.4693	5.9050	1.6534	1.6369	8.3570	2.3400	2.3166
185	apple pie, frozen, heated	other	apples	0.21	0.14	0.224	0.0470	0.0066	1.6930	0.3555	0.0498	5.9050	1.2401	0.1736	8.3570	1.7550	0.2457
187	candy, plain milk chocolate	other	cocoa fat	0.03	1.00	0.220	0.0066	0.0066	2.6510	0.0795	0.0795	5.7000	0.1710	0.1710	5.7880	0.1736	0.1736
187	candy, plain milk chocolate	other	sugar	0.52	0.99	0.220	0.1144	0.1133	2.6510	1.3785	1.3647	5.7000	2.9640	2.9344	5.7880	3.0098	2.9797
187	candy, plain milk chocolate	other	cocoa	0.22	0.99	0.220	0.0484	0.0479	2.6510	0.5832	0.5774	5.7000	1.2540	1.2415	5.7880	1.2734	1.2606
188	candy, carmels	other	sugar	0.70	0.99	0.075	0.0525	0.0520	1.8790	1.3153	1.3021	2.8520	1.9964	1.9764	2.4330	1.7031	1.6861
188	candy, carmels	other	cocoa, based on chocolate	0.04	0.99	0.075	0.0030	0.0030	1.8790	0.0752	0.0744	2.8520	0.1141	0.1129	2.4330	0.0973	0.0963
188	candy, carmels	other	cocoa fat	0.07	1.00	0.075	0.0053	0.0053	1.8790	0.1315	0.1315	2.8520	0.1996	0.1996	2.4330	0.1703	0.1703
189	chocolate powder,sweetened,to mix w/ hot or cold milk	other	sugar	0.52	0.99	0.095	0.0494	0.0489	0.5730	0.2980	0.2950	0.6590	0.3427	0.3393	1.1200	0.5824	0.5766
189	chocolate powder,sweetened,to mix w/ hot or cold milk	other	cocoa fat	0.11	1.00	0.095	0.0105	0.0105	0.5730	0.0630	0.0630	0.6590	0.0725	0.0725	1.1200	0.1232	0.1232
189	chocolate powder,sweetened,to mix w/ hot or cold milk	other	cocoa	0.37	0.99	0.095	0.0352	0.0348	0.5730	0.2120	0.2099	0.6590	0.2438	0.2414	1.1200	0.4144	0.4103
190	gelatin dessert, prepared, strawberry	other	sugar and gelatin	0.03	0.98	3.724	0.1117	0.1095	5.0160	0.1505	0.1475	6.0950	0.1828	0.1792	6.0380	0.1611	0.1775
191	carbonated soda, sweetened, cola type, canned	other	sugars, syrups and flavorings	0.02	0.91	3.949	0.0790	0.0719	43.6680	0.8734	0.7948	142.6500	2.8530	2.5962	165.6050	3.3121	3.0140
192	carbonated soda, sweetened, lemon-lime, canned	other	sugars, syrups and flavorings	0.02	0.91	4.512	0.0902	0.0821	19.4090	0.3882	0.3532	65.3080	1.3062	1.1886	92.7100	1.8542	1.6873
193	soft drink from powder, cherry flavor, presweetened	other	sugar and mix	0.02	0.99	18.834	0.3767	0.3729	76.5050	1.5701	1.5544	48.4220	0.9684	0.9568	69.2580	1.3852	1.3713
194	soda, low calorie, cola, sweetened w/saccharine, canned	other	flavor, saccarine	0.02	0.99	0.505	0.0101	0.0100	6.8180	0.1364	0.1350	23.5660	0.4713	0.4666	15.9410	0.3188	0.3156
195	coffee beverage, from instant	other	water	0.98	0.00	0.274	0.2685	0.0000	2.1620	2.1188	0.0000	24.4320	23.9434	0.0000	26.2370	25.7123	0.0000
195	coffee beverage, from instant	other	coffee beans	0.02	0.01	0.274	0.0055	0.0001	2.1620	0.0432	0.0004	24.4320	0.4886	0.0049	26.2370	0.5247	0.0052
196	coffee beverage, from instant, decaffeinated	other	water	0.98	0.00	0.030	0.0294	0.0000	0.3400	0.3332	0.0000	3.1940	3.1301	0.0000	1.6350	1.6023	0.0000
196	coffee beverage, from instant, decaffeinated	other	coffee beans	0.02	0.01	0.030	0.0006	0.0000	0.3400	0.0068	0.0001	3.1940	0.0639	0.0006	1.6350	0.0327	0.0003
197	tea beverage, hot, made with tea bag	other	water	0.98	0.00	8.690	8.5162	0.0000	31.6370	31.0043	0.0000	78.9570	77.3779	0.0000	86.8740	85.1365	0.0000
197	tea beverage, hot, made with tea bag	other	tea	0.02	0.98	8.690	0.1738	0.1703	31.6370	0.6327	0.6201	78.9570	1.5791	1.5476	86.8740	1.7375	1.7027
199	wine, table, 12.2% alcohol	other	grape-derived alcohol & solids	0.14	1.00	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3350	0.0469	0.0469	0.7210	0.1009	0.1009
200	whisky, 80-proof	other	alcohol & solids	0.33	1.00	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0880	0.0290	0.0290	0.3040	0.1003	0.1003
202	milk-based infant formula w/iron,canned,ready-to serve	other	sugars, syrups	0.32	0.99	47.728	15.2730	15.1202	0.6820	0.2182	0.2161	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
203	milk-based infant formula w/o iron,canned,ready-to-serv	other	sugar, syrups	0.32	0.99	81.931	26.2179	25.9557	1.9000	0.6080	0.6019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
154	fr. dinner:fr.chicken,mash pot.,cornbr.&/or veg.,heated	other	sugar	0.02	0.99	1.3990	0.0280	0.0277	1.2230	0.0245	0.0242	1.2620	0.0252	0.0250	1.9460	0.0389	0.0385
158	beef bouillon, canned, reconstituted with water	other	sugar	0.25	0.99	8.0130	2.0033	1.9832	3.1020	0.7755	0.7677	3.7540	0.9385	0.9291	4.1780	1.0445	1.0341
159	gravy, brown, from mix	other	sugar	0.01	0.99	3.6920	0.0369	0.0366	7.9410	0.0794	0.0786	4.1410	0.0414	0.0410	8.5360	0.0854	0.0845
168	cream substitute, powdered	other	vegetable fat & sweetener	1.00	0.10	0.9620	0.9620	0.0962	1.4180	1.4180	0.1418	1.6410	1.6410	0.1641	2.3220	2.3220	0.2322
169	sugar, white, granulated	other		1.00	0.99	5.4480	5.4480	5.3935	8.3830	8.3830	8.2992	5.1860	5.1860	5.1341	7.8650	7.8650	7.7864
170	syrup, pancake, bottled	other	sugar	0.51	0.99	2.2130	1.1286	1.1173	3.5170	1.7937	1.7757	1.4880	0.7589	0.7513	3.0990	1.5805	1.5647
171	jelly, grape, bottled	other	fruit	0.25	0.37	2.2110	0.5528	0.2045	3.4060	0.8515	0.3151	2.7030	0.6758	0.2500	4.2080	1.0520	0.3892
171	jelly, grape, bottled	other	sugar	0.75	0.99	2.2110	1.6583	1.6417	3.4060	2.5545	2.5290	2.7030	2.0273	2.0070	4.2080	3.1560	3.1244
172	honey, bottled	other		1.00	0.83	0.4890	0.4890	0.4059	0.8730	0.8730	0.7246	0.6650	0.6650	0.5520	0.8240	0.8240	0.6839
173	catsup, bottled	other	sugar	0.25	0.99	1.6620	0.4155	0.4113	4.2630	1.0658	1.0551	0.7940	0.1985	0.1965	0.8150	0.2038	0.2017
173	catsup, bottled	other	vinegar	0.30	0.01	1.6620	0.4986	0.0050	4.2630	1.2789	0.0128	0.7940	0.2382	0.0024	0.8150	0.2445	0.0024
174	ice cream, chocolate	other	sugar	0.15	0.99	9.3590	1.4039	1.3898	13.4990	2.0249	2.0046	11.3030	1.6955	1.6785	17.7550	2.6632	2.6366
175	pudding, chocolate, instant, made with whole milk	other	sugar	0.81	0.99	2.6720	2.1643	2.1427	3.8430	3.1128	3.0817	4.7000	3.8070	3.7689	5.1830	4.1982	4.1562
176	ice cream sandwich	other	sugar	0.15	0.99	0.6610	0.0992	0.0982	0.5560	0.0834	0.0826	0.3690	0.0553	0.0548	0.5840	0.0876	0.0867
177	ice milk, vanilla	other	sugar	0.15	0.99	1.8990	0.2849	0.2820	2.0470	0.3071	0.3040	2.9220	0.4383	0.4339	2.4560	0.3684	0.3647
178	chocolate cake w/chocolate icing, (ready-to-eat/frozen)	other	sugar, cocoa	0.44	0.99	3.3420	1.4705	1.4558	5.9130	2.6017	2.5757	1.9840	0.8730	0.8642	3.4690	1.5264	1.5111
179	yellow cake prep. from mix w/white icing prep. from mix	other	sugar	0.44	0.99	5.5890	2.4592	2.4346	8.9790	3.9508	3.9113	6.8930	3.0329	3.0026	8.2560	3.6326	3.5963
180	coffeecake, (ready-to-eat/frozen)	other	sugar, etc.	0.22	0.99	0.7440	0.1637	0.1620	1.3960	0.3071	0.3040	1.1990	0.2638	0.2611	1.4900	0.3278	0.3245
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	other	sugar	0.25	0.99	3.6910	0.9228	0.9135	5.6830	1.4208	1.4065	2.3070	0.5768	0.5710	4.7270	1.1818	1.1699
182	Danish pastry/sweet roll, (ready-to-eat/frozen)	other	sugar	0.07	0.99	2.0300	0.1421	0.1407	3.6500	0.2555	0.2529	2.5210	0.1765	0.1747	3.1590	0.2211	0.2189
183	cookies, chocolate chip	other	sugar	0.26	0.99	3.7510	0.9753	0.9655	4.7230	1.2280	1.2157	3.0840	0.8018	0.7938	4.5760	1.1898	1.1779
183	cookies, chocolate chip	other	chocolate chips	0.07	0.98	3.7510	0.2626	0.2573	4.7230	0.3306	0.3240	3.0840	0.2159	0.2116	4.5760	0.3203	0.3139
184	cookies, sandwich type, chocolate w/white cream filling	other	sugar	0.36	0.99	1.6480	0.5933	0.5873	2.7150	0.9774	0.9676	1.0520	0.3787	0.3749	2.4320	0.8755	0.8668
185	apple pie, frozen, heated	other	sugar	0.28	0.99	4.8960	1.3709	1.3572	7.3590	2.0605	2.0399	6.2920	1.7590	1.7414	8.7150	2.4402	2.4158
185	apple pie, frozen, heated	other	apples	0.21	0.14	4.8960	1.0282	0.1439	7.3590	1.5454	0.2164	6.2820	1.3192	0.1847	8.7150	1.8302	0.2562
187	candy, plain milk chocolate	other	cocoa fat	0.03	1.00	2.7970	0.0839	0.0839	4.0900	0.1227	0.1227	1.9950	0.0599	0.0599	1.9000	0.0570	0.0570
187	candy, plain milk chocolate	other	sugar	0.52	0.99	2.7970	1.4544	1.4399	4.0900	2.1268	2.1055	1.9950	1.0374	1.0270	1.9000	0.9880	0.9781
187	candy, plain milk chocolate	other	cocoa	0.22	0.99	2.7970	0.6153	0.6092	4.0900	0.8998	0.8908	1.9950	0.4389	0.4345	1.9000	0.4180	0.4138
188	candy, carmels	other	sugar	0.70	0.99	1.6330	1.1431	1.1317	4.0590	2.8413	2.8129	1.1240	0.7868	0.7789	1.1850	0.8295	0.8212
188	candy, carmels	other	cocoa, based on chocolate	0.04	0.99	1.6330	0.0653	0.0647	4.0590	0.1624	0.1607	1.1240	0.0450	0.0445	1.1850	0.0474	0.0469
188	candy, carmels	other	cocoa fat	0.07	1.00	1.6330	0.1143	0.1143	4.0570	0.2841	0.2841	1.1240	0.0787	0.0787	1.1850	0.0830	0.0830
189	chocolate powder,sweetened,to mix w/ hot or cold milk	other	sugar	0.52	0.99	0.9660	0.5023	0.4973	0.7380	0.3838	0.3799	0.3580	0.1862	0.1843	0.8490	0.4415	0.4371
189	chocolate powder,sweetened,to mix w/ hot or cold milk	other	cocoa fat	0.11	1.00	0.9660	0.1063	0.1063	0.7380	0.0812	0.0812	0.3580	0.0394	0.0394	0.8490	0.0934	0.0934
189	chocolate powder,sweetened,to mix w/ hot or cold milk	other	cocoa	0.37	0.99	0.9660	0.3574	0.3538	0.7380	0.2731	0.2703	0.3580	0.1325	0.1311	0.8490	0.3141	0.3110
190	gelatin dessert, prepared, strawberry	other	sugar and gelatin	0.03	0.98	3.3430	0.1003	0.0983	3.4480	0.1034	0.1014	7.2010	0.2160	0.2117	8.4270	0.2528	0.2478
191	carbonated soda, sweetened, cola type, canned	other	sugars, syrups and flavorings	0.02	0.91	132.8390	2.6568	2.4177	214.5290	4.2906	3.9044	31.0400	0.6208	0.5649	48.2200	0.9644	0.8776
192	carbonated soda, sweetened, lemon-lime, canned	other	sugars, syrups and flavorings	0.02	0.91	41.6220	0.8324	0.7575	77.5290	1.5506	1.4110	19.2470	0.3849	0.3503	22.0920	0.4418	0.4021
193	soft drink from powder, cherry flavor, presweetened	other	sugar and mix	0.02	0.99	32.4900	0.6498	0.6433	19.2810	0.3856	0.3818	8.7020	0.1740	0.1723	14.2150	0.2843	0.2815
194	soda, low calorie, cola, sweetened w/saccharine, canned	other	flavor, saccarine	0.02	0.99	54.1960	1.0839	1.0731	23.1620	0.4632	0.4586	27.5490	0.5510	0.5455	15.1230	0.3025	0.2994
195	coffee beverage, from instant	other	water	0.98	0.00	283.4270	277.7585	0.0000	354.2040	347.1199	0.0000	372.0580	364.6168	0.0000	476.8290	467.2924	0.0000
195	coffee beverage, from instant	other	coffee beans	0.02	0.01	283.4270	5.6685	0.0567	354.2040	7.0841	0.0708	372.0580	7.4412	0.0744	476.8290	9.5366	0.0954
196	coffee beverage, from instant, decaffeinated	other	water	0.98	0.00	17.2540	16.9089	0.0000	20.9430	20.5241	0.0000	75.9430	74.4241	0.0000	62.8620	61.6048	0.0000
196	coffee beverage, from instant, decaffeinated	other	coffee beans	0.02	0.01	17.2540	0.3451	0.0035	20.9430	0.4189	0.0042	75.9430	1.5189	0.0152	62.8620	1.2572	0.0126
197	tea beverage, hot, made with tea bag	other	water	0.98	0.00	163.3330	160.0663	0.0000	143.7860	140.9103	0.0000	153.8370	150.7603	0.0000	97.5230	95.5725	0.0000
197	tea beverage, hot, made with tea bag	other	tea	0.02	0.98	163.3330	3.2667	3.2013	143.7860	2.8757	2.8182	153.8370	3.0767	3.0152	97.5230	1.9505	1.9115
199	wine, table, 12.2% alcohol	other	grape-derived alcohol & solids	0.14	1.00	11.9250	1.6695	1.6695	11.2890	1.5805	1.5805	5.1640	0.7230	0.7230	8.6230	1.2072	1.2072
200	whisky, 80-proof	other	alcohol & solids	0.33	1.00	4.9360	1.6289	1.6289	8.5180	2.8109	2.8109	3.8940	1.2850	1.2850	8.5750	2.8297	2.8297
202	milk-based infant formula w/iron,canned,ready-to serve	other	sugars, syrups	0.32	0.99	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
203	milk-based infant formula w/o iron,canned,ready-to-serv	other	sugar, syrups	0.32	0.99	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	6-11 MO. UNADJ.	6-11 MO. WET WT.	6-11 MO. DRY WT.	2 YR. UNADJ.	2 YR. WET WT.	2 YR. DRY WT.	14-16 F UNADJ.	14-16 F WET WT.	14-16 F DRY WT.	14-16 M UNADJ.	14-16 M WET WT.	14-16 M DRY WT.
217	oatmeal with applesauce and bananas, (st./jr.)	other	fruits; apples & bananas	0.29	0.20	16.077	4.6623	0.9325	0.3160	0.0916	0.0183	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
225	applesauce/applesauce with other fruit, (st./jr.)	other	strained	1.00	0.11	21.957	21.9570	2.4153	0.2400	0.2400	0.0264	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
226	peaches, (st./jr.)	other	strained	1.00	0.20	19.434	19.4340	3.8868	0.1470	0.1470	0.0294	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
227	pear/pear and pineapple, (st./jr.)	other	strained	1.00	0.12	11.293	11.2930	1.3552	0.1720	0.1720	0.0206	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
228	bananas and pineapple with tapioca, (st./jr.)	other	strained	0.32	0.10	14.303	4.5770	0.4577	0.2570	0.0822	0.0082	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
229	prunes/plums with tapioca, (st./jr.)	other	strained prunes	0.32	0.10	4.479	1.4333	0.1433	0.3560	0.1139	0.0114	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
230	apple/apple chery/apple grape juice, strained	other	strained apples	1.00	0.12	18.324	18.3240	2.1989	0.9400	0.9400	0.1128	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
231	orange/orange pineapple juice, strained	other	strained oranges	1.00	0.12	8.220	8.2200	0.9864	0.6040	0.6040	0.0725	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
232	pudding/custard, any flavor, (st./jr.)	other	sugar	0.16	0.99	8.326	1.3322	1.3188	0.0150	0.0024	0.0024	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
233	fruit dessert with tapioca, any fruit, (st./jr.)	other	fruit, aggregate	0.32	0.10	4.392	1.4054	0.1405	0.4020	0.1286	0.0129	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
234	dutch apple/apple betty, (st./jr.)	other	apple	0.20	0.12	8.041	1.6082	0.1930	0.0606	0.0120	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
234	dutch apple/apple betty, (st./jr.)	other	sugar	0.29	0.99	8.041	2.3319	2.3086	0.0600	0.0174	0.0172	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		other-total					245.2675	78.8062		264.1923	67.7638		318.1710	85.1162		400.4057	127.2669
058	whitebread, enriched	water		0.37	0.00	6.303	2.3321	0.0000	26.8370	9.9297	0.0000	38.7510	14.3379	0.0000	55.6780	20.6009	0.0000
061	biscuits,baking powder,enriched,refrigerated type,baked	water		0.28	0.00	0.620	0.1736	0.0000	2.5820	0.7230	0.0000	3.6680	1.0270	0.0000	4.8560	1.3597	0.0000
062	whole wheat bread	water		0.31	0.00	0.653	0.2024	0.0000	2.7060	0.8389	0.0000	2.1560	0.6684	0.0000	3.3770	1.0469	0.0000
064	rye bread	water		0.37	0.00	0.082	0.0303	0.0000	0.6870	0.2542	0.0000	0.9140	0.3382	0.0000	0.7240	0.2679	0.0000
067	noodles, egg, enriched, cooked	water		0.61	0.00	0.7910	0.4825	0.0000	1.4090	0.8595	0.0000	1.7470	1.0657	0.0000	3.4270	2.0905	0.0000
135	mashed potatoes w/marg. & milk, prepared from instant	water		0.52	0.00	7.389	3.8423	0.0000	9.8790	5.1371	0.0000	15.0040	7.8021	0.0000	24.5260	12.7535	0.0000
142	spaghetti with meat sauce, homemade	water		0.44	0.00	4.786	2.1058	0.0000	16.4100	7.2204	0.0000	17.4770	7.6899	0.0000	33.5700	14.7708	0.0000
146	macaroni and cheese, prepared from box mix	water		0.29	0.00	3.545	1.0281	0.0000	7.4810	2.1695	0.0000	8.4490	2.4502	0.0000	12.0250	3.4873	0.0000
153	pork chow mein, homemade	water		0.58	0.00	0.321	0.1862	0.0000	0.8090	0.4692	0.0000	2.0730	1.2023	0.0000	3.1190	1.8090	0.0000
155	chicken noodle soup, canned, reconstituted with water	water		0.89	0.00	6.835	6.0832	0.0000	17.8080	15.8491	0.0000	12.6120	11.2247	0.0000	7.0820	6.3030	0.0000
157	vegetable beef soup, canned, reconstituted with water	water		0.90	0.00	5.792	5.2128	0.0000	16.1960	14.5764	0.0000	12.1130	10.9017	0.0000	13.2320	11.9088	0.0000
158	beef bouillon, canned, reconstituted with water	water		0.91	0.00	0.274	0.2493	0.0000	1.0490	0.9546	0.0000	0.7770	0.7071	0.0000	1.1820	1.0756	0.0000
159	gravy, brown, from mix	water		0.98	0.00	1.891	1.8532	0.0000	3.5130	3.4427	0.0000	6.1630	6.0397	0.0000	7.3600	7.2128	0.0000
176	syrup, pancake, bottled	water		0.27	0.00	0.561	0.1515	0.0000	2.4540	0.6626	0.0000	3.6300	0.9801	0.0000	5.9630	1.6100	0.0000
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	water		0.14	0.00	0.516	0.0722	0.0000	2.3650	0.3311	0.0000	4.0180	0.5625	0.0000	6.6590	0.9323	0.0000
190	gelatin dessert, prepared, strawberry	water		0.97	0.00	3.724	3.6123	0.0000	5.0160	4.8655	0.0000	6.0950	5.9122	0.0000	6.0380	5.8569	0.0000
191	carbonated soda, sweetened, cola type, canned	water		0.98	0.00	3.949	3.8700	0.0000	43.6680	42.7946	0.0000	142.6500	139.7970	0.0000	165.6050	162.2929	0.0000
192	carbonated soda, sweetened, lemon-lime, canned	water		0.98	0.00	4.512	4.4218	0.0000	19.4090	19.0208	0.0000	65.3080	64.0018	0.0000	92.7100	90.8558	0.0000
193	soft drink from powder, cherry flavor, presweetened	water		0.98	0.00	18.834	18.4573	0.0000	76.5050	76.9349	0.0000	48.4220	47.4536	0.0000	69.2580	67.8728	0.0000
194	soda, low calorie, cola, sweetened w/saccharine, canned	water		0.98	0.00	0.505	0.4949	0.0000	6.8180	6.6816	0.0000	23.5660	23.0947	0.0000	15.9410	15.6222	0.0000
198	beer, canned	water		0.92	0.00	0.024	0.0221	0.0000	0.0570	0.0524	0.0000	0.0710	0.0653	0.0000	16.1190	14.8295	0.0000
199	wine, table, 12.2% alcohol	water		0.86	0.00	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3350	0.2881	0.0000	0.7210	0.6201	0.0000
200	whisky, 80-proof	water		0.67	0.00	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0880	0.0590	0.0000	0.3040	0.2037	0.0000
201	water	water		1.00	0.00	150.000	150.0000	0.0000	321.0000	321.0000	0.0000	432.0000	432.0000	0.0000	548.0000	548.0000	0.0000
214	chicken and noodles, (st./jr.)	water		0.60	0.00	9.458	5.6748	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
215	tomatoes, beef and macaroni, (st./jr.)	water		0.50	0.00	3.958	1.9790	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
217	oatmeal with applesauce and bananas, (st./jr.)	water		0.58	0.00	16.077	9.3247	0.0000	0.3160	0.1833	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
228	bananas and pineapple with tapioca, (st./jr.)	water		0.47	0.00	14.303	6.7224	0.0000	0.2570	0.1208	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
229	prunes/plums with tapioca, (st./jr.)	water		0.47	0.00	4.479	2.1051	0.0000	0.3560	0.1673	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
232	pudding/custard, any flavor, (st./jr.)	water		0.74	0.00	8.326	6.1612	0.0000	0.0150	0.0111	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
233	fruit dessert with tapioca, any fruit, (st./jr.)	water		0.47	0.00	4.392	2.0642	0.0000	0.4020	0.1889	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
234	dutch apple/apple betty, (st./jr.)	water		0.47	0.00	8.041	3.7793	0.0000	0.0600	0.0282	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		water-total					242.6946	0.0000		535.4675	0.0000		779.6691	0.0000		993.3826	0.0000

Table A1-3: Part B - Meat, Dairy and Other

ITEM NUM.	ITEM NAME	CATEGORY	COMMENTS	FRACT	% DM	25-30 F UNADJ.	25-30 F WET WT.	25-30 F DRY WT.	25-30 M UNADJ.	25-30 M WET WT.	25-30 M DRY WT.	60-65 F UNADJ.	60-65 F WET WT.	60-65 F DRY WT.	60-65 M UNADJ.	60-65 M WET WT.	60-65 M DRY WT.
217	oatmeal with applesauce and bananas, (st./jr.)	other	fruits; apples & bananas	0.29	0.20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
225	applesauce/applesauce with other fruit, (st./jr.)	other	strained	1.00	0.11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
226	peaches, (st./jr.)	other	strained	1.00	0.20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
227	pear/pear and pineapple, (st./jr.)	other	strained	1.00	0.12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
228	bananas and pineapple with tapioca, (st./jr.)	other	strained	0.32	0.10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
229	prunes/plums with tapioca, (st./jr.)	other	strained prunes	0.32	0.10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
230	apple/apple chery/apple grape juice, strained	other	strained apples	1.00	0.12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
231	orange/orange pineapple juice, strained	other	strained oranges	1.00	0.12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
232	pudding/custard, any flavor, (st./jr.)	other	sugar	0.16	0.99	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
233	fruit dessert with tapioca, any fruit, (st./jr.)	other	fruit, aggregate	0.32	0.10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
234	dutch apple/apple betty, (st./jr.)	other	apple	0.20	0.12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
234	dutch apple/apple betty, (st./jr.)	other	sugar	0.29	0.99	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		other-total					684.4461	80.8883		770.1192	105.5348		658.2119	78.6520		890.3108	94.0083
058	whitebread, enriched	water		0.37	0.00	34.4240	12.7369	0.0000	36.7200	13.5864	0.0000	34.9880	12.9456	0.0000	50.8730	18.8230	0.0000
061	biscuits,baking powder,enriched,refrigerated type,baked	water		0.28	0.00	3.0630	0.8576	0.0000	5.0310	1.4087	0.0000	4.0800	1.1424	0.0000	7.8060	2.1857	0.0000
062	whole wheat bread	water		0.31	0.00	4.1780	1.2952	0.0000	7.7820	2.4124	0.0000	5.4900	1.7019	0.0000	6.5870	2.0420	0.0000
064	rye bread	water		0.37	0.00	0.9470	0.3504	0.0000	0.9450	0.3496	0.0000	1.0140	0.3752	0.0000	0.8380	0.3101	0.0000
069	noodles, egg, enriched, cooked	water		0.61	0.00	1.8590	1.1340	0.0000	2.4990	1.5244	0.0000	1.2100	0.7381	0.0000	2.3260	1.4189	0.0000
135	mashed potatoes w/marg. & milk, prepared from instant	water		0.52	0.00	11.6100	6.0372	0.0000	18.6350	9.7942	0.0000	10.4050	5.4106	0.0000	17.0150	8.8478	0.0000
142	spaghetti with meat sauce, homemade	water		0.44	0.00	15.5010	6.8204	0.0000	23.9170	10.5235	0.0000	8.9560	3.9406	0.0000	11.0850	4.8774	0.0000
146	macaroni and cheese, prepared from box mix	water		0.29	0.00	7.4000	2.1460	0.0000	8.6990	2.5227	0.0000	5.1060	1.4807	0.0000	4.4730	1.2972	0.0000
153	pork chow mein, homemade	water		0.58	0.00	3.8240	2.2179	0.0000	4.5130	2.6175	0.0000	2.9200	1.6936	0.0000	2.9040	1.6843	0.0000
155	chicken noodle soup, canned, reconstituted with water	water		0.89	0.00	7.0920	6.3119	0.0000	7.5110	6.6848	0.0000	8.2750	7.3648	0.0000	14.2020	12.6398	0.0000
157	vegetable beef soup, canned, reconstituted with water	water		0.90	0.00	5.8700	5.2830	0.0000	15.0990	13.5891	0.0000	21.8390	19.6551	0.0000	20.5360	18.4824	0.0000
158	beef bouillon, canned, reconstituted with water	water		0.91	0.00	8.0130	7.2918	0.0000	3.1020	2.8228	0.0000	3.7540	3.4161	0.0000	4.1780	3.8020	0.0000
159	gravy, brown, from mix	water		0.98	0.00	3.6920	3.6182	0.0000	7.9410	7.7822	0.0000	4.1410	4.0582	0.0000	8.5360	8.3653	0.0000
170	syrup, pancake, bottled	water		0.27	0.00	2.2130	0.5975	0.0000	3.5170	0.9496	0.0000	1.4880	0.4018	0.0000	3.0990	0.8367	0.0000
181	doughnuts, cake type, plain, (ready-to-eat/frozen)	water		0.14	0.00	3.6910	0.5167	0.0000	5.6830	0.7956	0.0000	2.3070	0.3230	0.0000	4.7270	0.6618	0.0000
190	gelatin dessert, prepared, strawberry	water		0.97	0.00	3.3430	3.2427	0.0000	3.4480	3.3446	0.0000	7.2010	6.9850	0.0000	8.4270	8.1742	0.0000
191	carbonated soda, sweetened, cola type, canned	water		0.98	0.00	132.8390	130.1822	0.0000	214.5290	210.2384	0.0000	31.0400	30.4192	0.0000	48.2200	47.2556	0.0000
192	carbonated soda, sweetened, lemon-lime, canned	water		0.98	0.00	41.6220	40.7896	0.0000	77.5290	75.9784	0.0000	19.2470	18.8621	0.0000	22.0920	21.6502	0.0000
193	soft drink from powder, cherry flavor, presweetened	water		0.98	0.00	32.4900	31.8402	0.0000	19.2810	18.8954	0.0000	8.7020	8.5280	0.0000	14.2150	13.9307	0.0000
194	soda, low calorie, cola, sweetened w/saccharine, canned	water		0.98	0.00	54.1960	53.1121	0.0000	23.1620	22.6988	0.0000	27.5490	26.9980	0.0000	15.1230	14.8205	0.0000
198	beer, canned	water		0.92	0.00	34.5910	31.8237	0.0000	299.2020	275.2658	0.0000	9.2910	8.5477	0.0000	98.4790	90.6007	0.0000
199	wine, table, 12.2% alcohol	water		0.86	0.00	11.9250	10.2555	0.0000	11.2890	9.7085	0.0000	5.1640	4.4410	0.0000	8.6230	7.4158	0.0000
200	whisky, 80-proof	water		0.67	0.00	4.9360	3.3071	0.0000	8.5180	5.7071	0.0000	3.8940	2.6090	0.0000	8.5750	5.7452	0.0000
201	water	water		1.00	0.00	399.0000	399.0000	0.0000	512.0000	512.0000	0.0000	546.0000	546.0000	0.0000	581.0000	581.0000	0.0000
214	chicken and noodles, (st./jr.)	water		0.60	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
215	tomatoes, beef and macaroni, (st./jr.)	water		0.50	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
217	oatmeal with applesauce and bananas, (st./jr.)	water		0.58	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
228	bananas and pineapple with tapioca, (st./jr.)	water		0.47	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
229	prunes/plums with tapioca, (st./jr.)	water		0.47	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
232	pudding/custard, any flavor, (st./jr.)	water		0.74	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
233	fruit dessert with tapioca, any fruit, (st./jr.)	water		0.47	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
234	dutch apple/apple betty, (st./jr.)	water		0.47	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		water-total					760.7679	0.0000		1211.2006	0.0000		718.0376	0.0000		876.8671	0.0000

APPENDIX 2

PARAMETER GUIDANCE FOR USLE PARAMETERS

Soil losses that are due to runoff of precipitation (sheet and rill erosion) can be predicted for a given site using the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). This empirical equation uses site-specific values for the various input parameters of interrelated physical factors and soil management practices. Tables and maps are provided for use in selecting site-specific values for these factors. Useful procedures for the estimation of USLE parameters for agricultural and nonagricultural conditions can be found in Mills et al. (1982) and Wischmeier and Smith (1978).

The USLE defines loss as follows:

$$L = R \times K \times LS \times C \times P \qquad \text{(A2-1)}$$

where:

L = computed average annual soil loss (tons/acre/year)

R = rainfall erosion index (year^{-1})

K = soil erodibility factor (tons/acre per unit of rainfall factor, R)

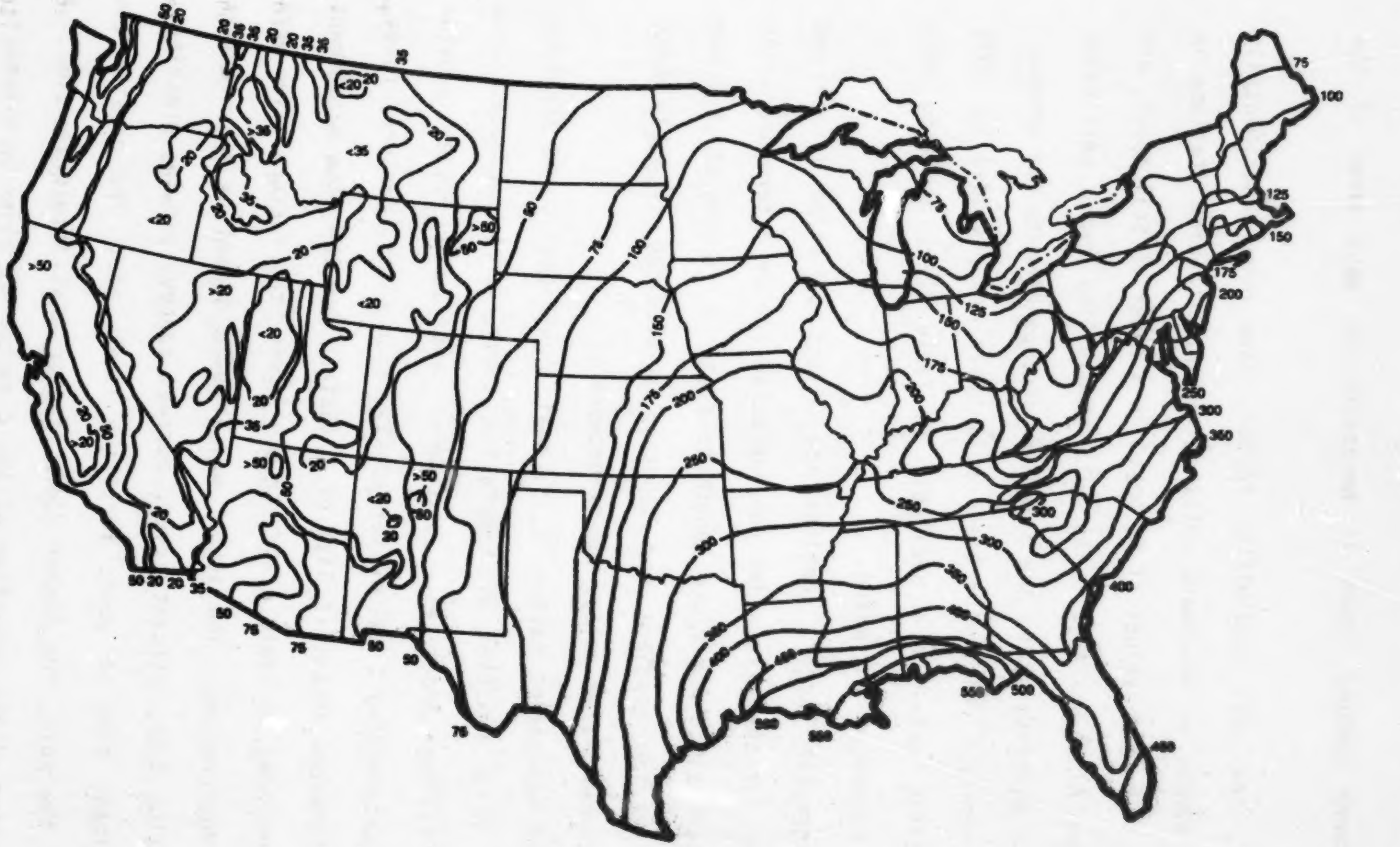
LS = topographic factor (dimensionless)

C = cover and management factor (dimensionless)

P = support practice factor (dimensionless)

L, the average annual soil loss per unit area, represents an average annual value and is obtained by multiplying the rainfall erosion index, which provides estimated soil losses from rainfall and runoff for a geographic area, by a series of ratios. These ratios represent the relationship of actual parameters to those observed in test soils and standardized agricultural plots.

The rainfall erosion index, R, expresses erosion potential for average annual rainfall at a location. A map of average R values for the United States, based on over 30 years of measurements, is provided in Figure A2-1.



75
100
125
150
175
200
250
300
350
400
450
500
550
<20
>20
20
35
<35
>35
50
>50

FIGURE A2-1

Average Annual Values of the Rainfall Erosion Index, year^{-1}

Source: Wischmeier and Smith, 1978

Interpolation between contour lines is necessary for many areas of the country.

Values for K, the soil erodibility factor, have been experimentally determined for a number of benchmark soils at erosion research stations in the United States. Average values of K, based on a range of soil types, are provided in Tables A2-1 and A2-2. The soil erodibility for a particular site can be approximated by using the K value corresponding to the predominant soil type. Average values for basic soil types are provided in Table A2-1. More specific values are available in Table A2-2, assuming soil organic content is known or estimated.

LS, the topographic factor, combines the effect of slope length and steepness. Values for the area under consideration can be determined using the average percent slope and slope length in feet. A listing of LS values for slopes of varying gradient and lengths is provided in Table A2-3. Interpolation between listed values may be necessary.

The cover and management factor, C, is most significant on agricultural land where it is a function of vegetative cover, crop sequence, crop rotation, and tilling practices. Wischmeier and Smith (1978) provide guidelines for determining C values for construction sites, pasture, range, idle land and forested areas. A list of C factors for the five management practices are provided in Table A2-4. In all cases, the factors given were chosen to be conservative. The actual value would depend on many factors such as vegetation type, percent cover, percent canopy, plowing practices, rotation practiced, time of year, fertility level, etc. The greater the erodibility of the soil, the higher the C factor that should be used. A thorough discussion of the selection of the C factor is given in Wischmeier and Smith (1978).

TABLE A2-1

Average Values for the Soil Erodibility Factor K, for Soils on Erosion Research Stations*

Average Soil Type	K Value (tons/acre)
Silt loam Loam Sandy clay loam	0.4
Silty clay loam Clay Clay loam	0.3
Fine sandy loam	0.2
Loamy sand Flaggy silt loam	0.1
Gravelly loam	0.1

*Source: Wischmeier and Smith, 1978

TABLE A2-2

General Magnitude of the Soil/Erodibility Factor, K, when Organic Content Data are Available[a,b]

Texture Class	Organic Matter Content		
	0.5%	2%	4%
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13-0.29	

---

[a] Source: Carsel et al., 1984

[b] The values shown are estimated averages of broad ranges of specific-soil values. When a texture is near the borderline of two texture classes, use the average of the two K values. For specific soils, Soil Conservation Service K-value tables will provide much greater accuracy.

TABLE A2-3

Values of the Topographic Factor, LS, for Specific Combinations of Slope Length and Steepness*

Percent Slope	Slope Length (feet)											
	25	50	75	100	150	200	300	400	500	600	800	1000
0.2	0.060	0.069	0.075	0.080	0.086	0.092	0.099	0.105	0.110	0.114	0.121	0.126
0.5	0.073	0.083	0.090	0.096	0.104	0.110	0.119	0.126	0.132	0.137	0.145	0.152
0.8	0.086	0.098	0.107	0.113	0.123	0.130	0.141	0.149	0.156	0.162	0.171	0.179
2	0.133	0.163	0.185	0.201	0.227	0.248	0.280	0.305	0.326	0.344	0.376	0.402
3	0.190	0.233	0.264	0.287	0.325	0.354	0.400	0.437	0.466	0.492	0.536	0.573
4	0.230	0.303	0.357	0.400	0.471	0.528	0.621	0.697	0.762	0.820	0.920	1.01
5	0.268	0.379	0.464	0.536	0.656	0.758	0.928	1.07	1.20	1.31	1.52	1.69
6	0.336	0.476	0.583	0.673	0.824	0.952	1.17	1.35	1.50	1.65	1.90	2.13
8	0.496	0.701	0.859	0.992	1.21	1.41	1.72	1.98	2.22	2.43	2.81	3.14
10	0.685	0.968	1.19	1.37	1.68	1.94	2.37	2.74	3.06	3.36	3.87	4.33
12	0.903	1.28	1.56	1.80	2.21	2.55	3.13	3.61	4.04	4.42	5.11	5.71
14	1.15	1.62	1.99	2.30	2.81	3.25	3.98	4.59	5.13	5.62	6.49	7.26
16	1.42	2.01	2.46	2.84	3.48	4.01	4.92	5.68	6.35	6.95	8.03	8.98
18	1.72	2.43	2.97	3.43	4.21	3.86	5.95	6.87	7.68	8.41	9.71	10.9
20	2.04	2.38	3.53	4.08	5.00	5.77	7.07	8.16	9.12	10.0	11.5	12.9

*Source: Wischmeier and Smith, 1978

$LS = \lambda\ 72.6^{m}\ 65.41 \sin \theta - 4.56 \sin \theta - 0.065$ where λ = slope length in feet m = 0.2 for gradients <1% 0.3 for 1-3% slopes, 0.4 for 3.5-4.5% slopes, 0.5 for 5% slopes and steeper and θ = angle of slope. For other combinations of length and gradient interpolate between adjacent values.

TABLE A2-4

C Factors for the Five Management Practices*

Practice	C Factor
Land reclamation	0.6
Agricultural	0.5
Dedicated disposal	1.0
Forest application	0.6
Distribution and marketing	0.4

*Source: Wischmeier and Smith, 1978

The support practice factor, P, is also dependent on agricultural techniques, and is a function of such practices as contouring and terracing. Because there is no counterpart of P on natural land, horticultural areas, or construction sites, the value of P has been set at 1.

REFERENCES FOR APPENDIX 2

Carsel, R.F., C.N. Smith, L.A. Mulkey, J.D. Dean and P. Jowise. 1984. User's Manual for the pesticide root zone model (PRZM), release I, EPA/600/3-84-109. Prepared by Environmental Research Laboratory, Athens, GA. U.S. EPA, Washington, DC.

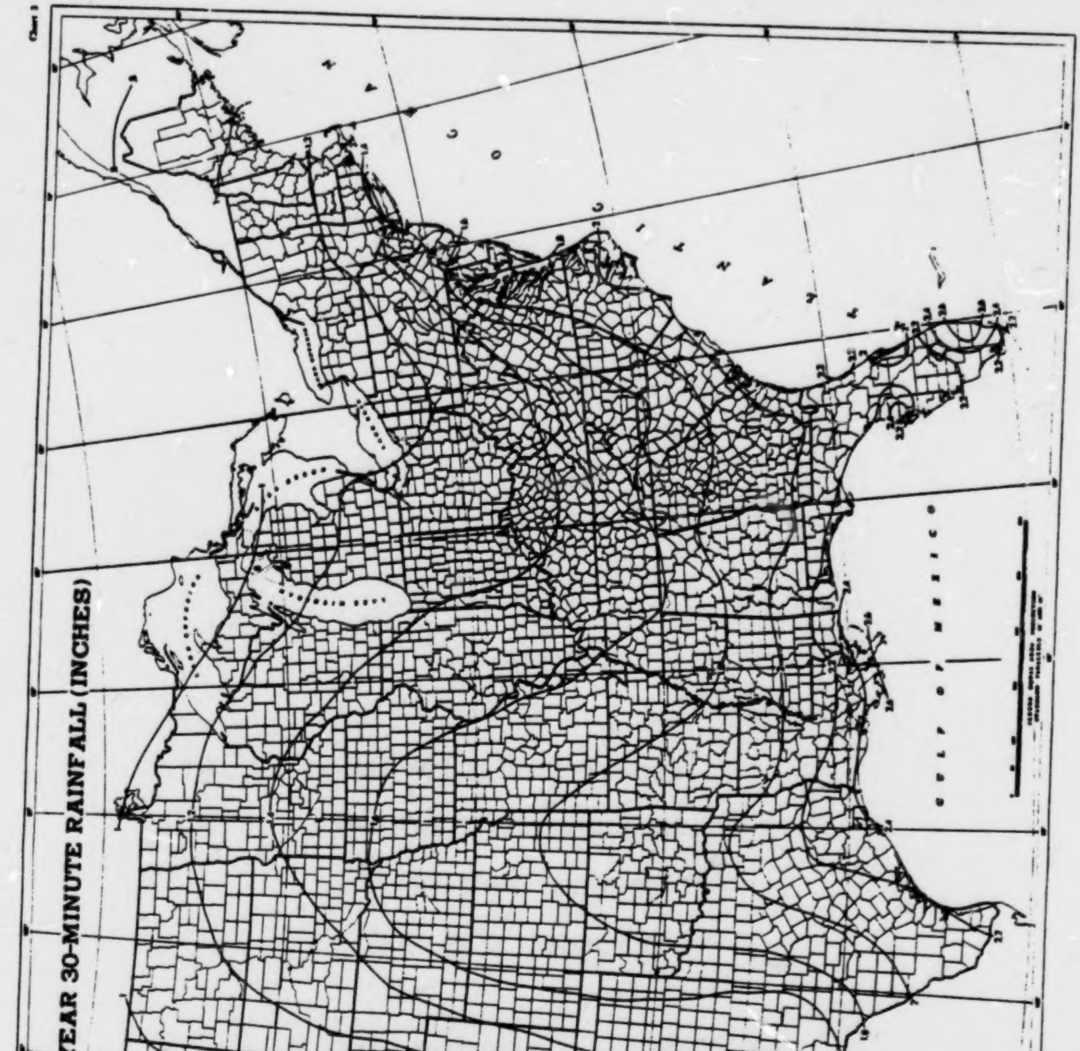
Mills, W.B., J.D. Dean, D.B. Porcella, et al. 1982. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants. Part 1. EPA-600/6-82-004a. U.S. EPA, Athens, GA.

Wischmeier, W.H. and D.D. Smith. 1978. Predicting Rainfall Erosion Losses -- A Guide to Conservation and Planning. USDA Handbook, No. 537, U.S. Department of Agriculture.

APPENDIX 3

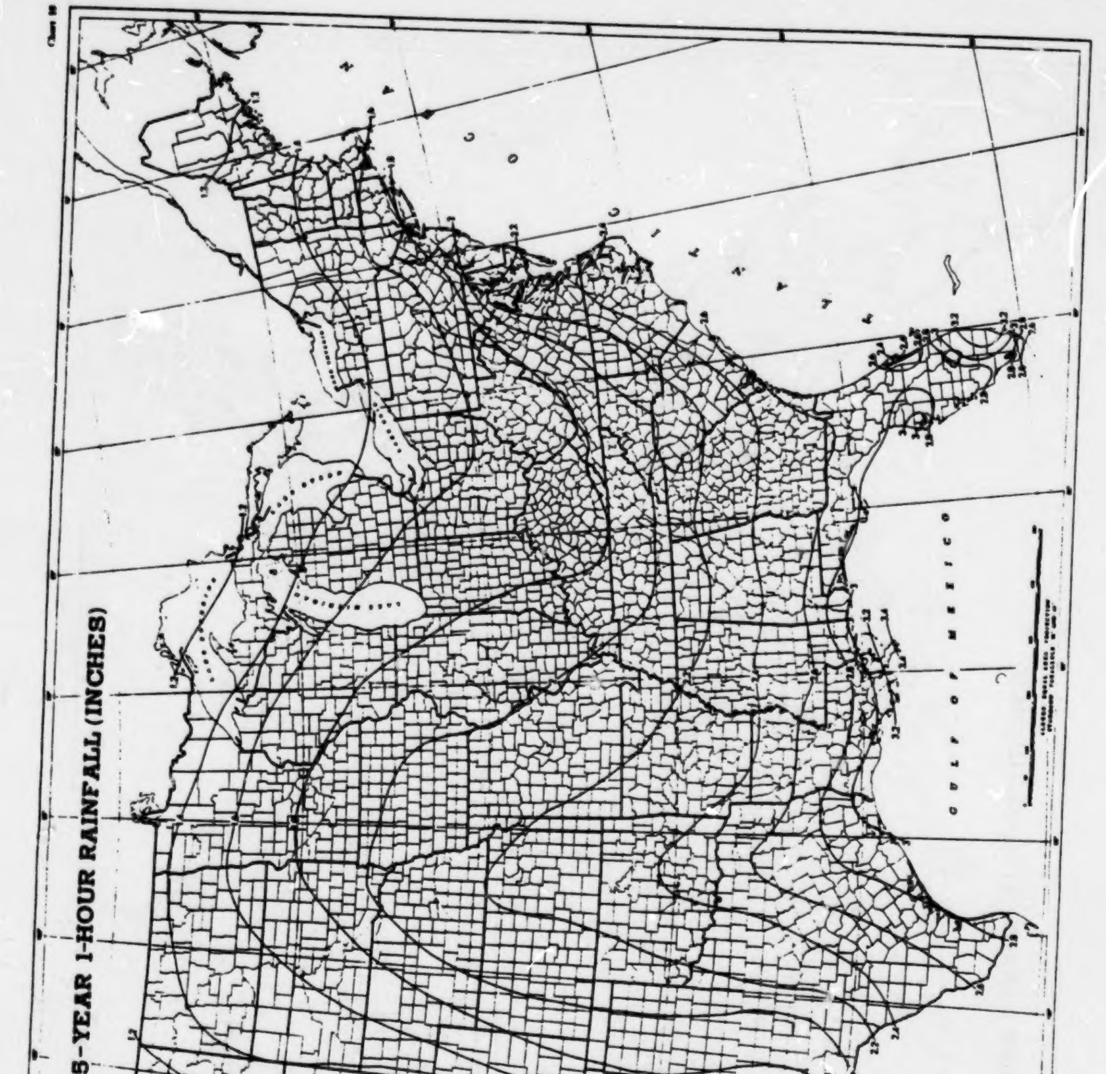
RAINFALL DEPTHS FOR THE 5-YEAR RECURRENCE INTERVAL FOR STORM DURATIONS OF 30 MINUTES TO 24 HOURS

Source: HERSCHFIELD, 1961



5-YEAR 30-MINUTE RAINFALL (INCHES)

PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO

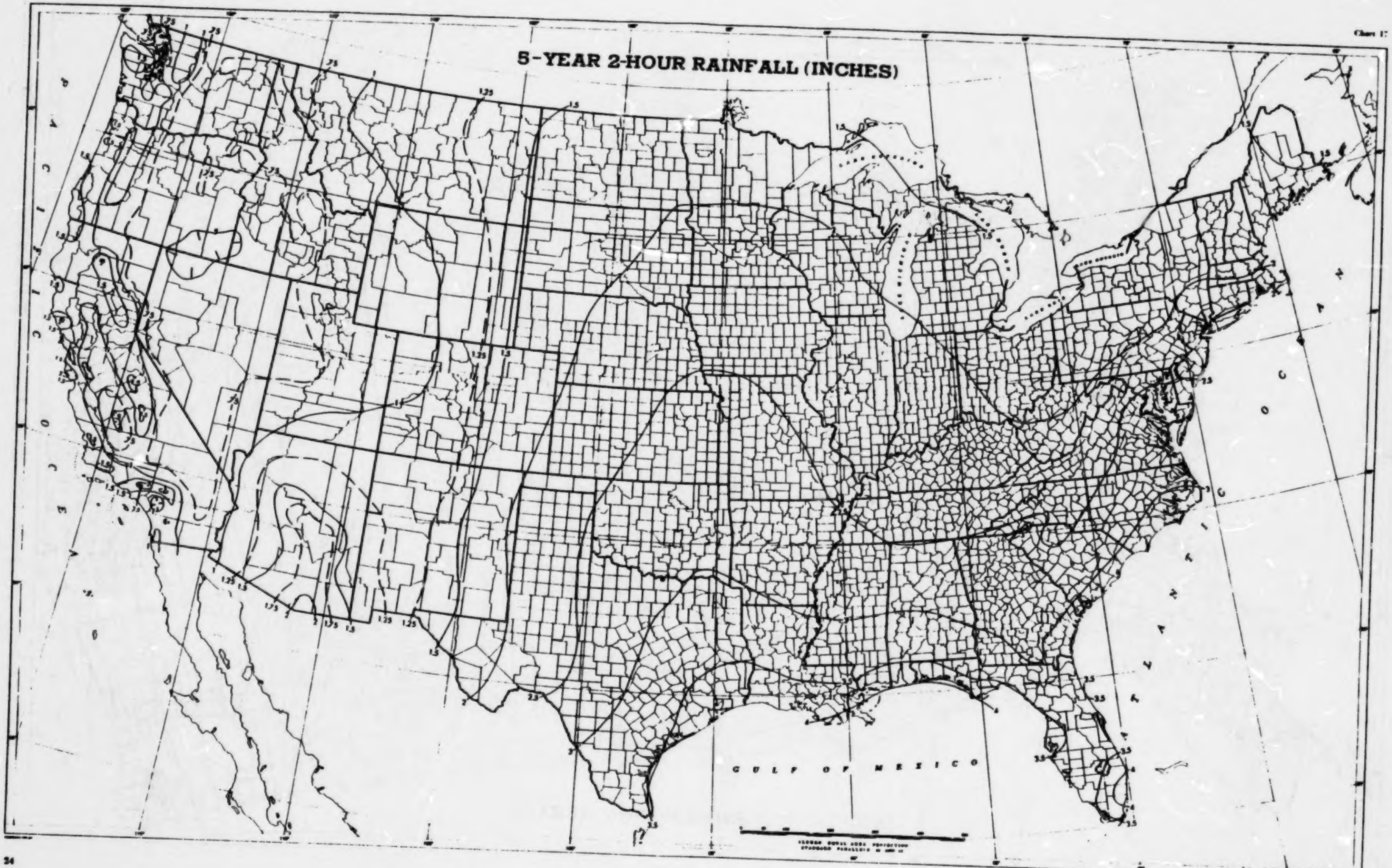


5-YEAR 1-HOUR RAINFALL (INCHES)

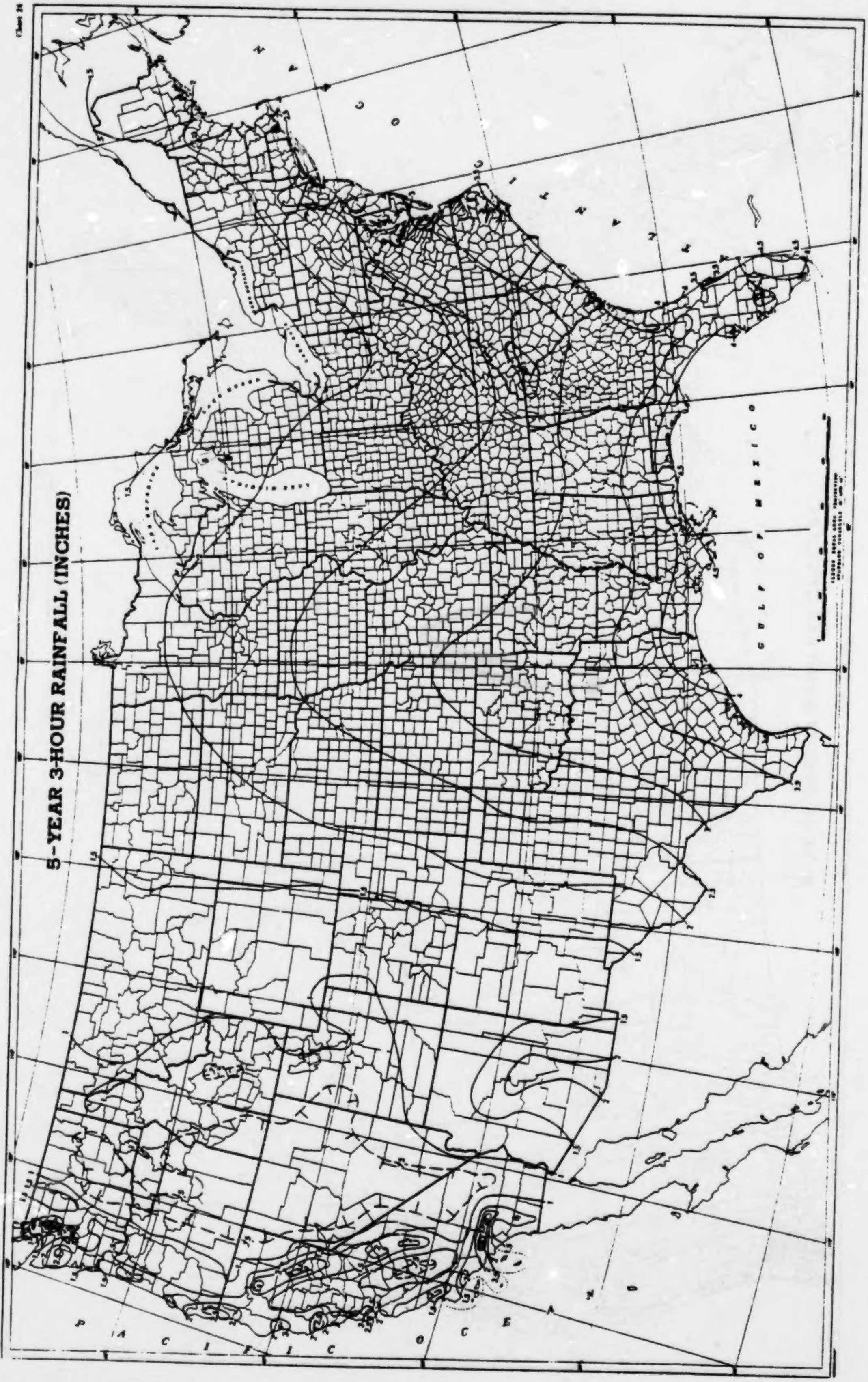
ATLANTIC OCEAN
GULF OF MEXICO
PACIFIC OCEAN
17

Chart 17

5-YEAR 2-HOUR RAINFALL (INCHES)

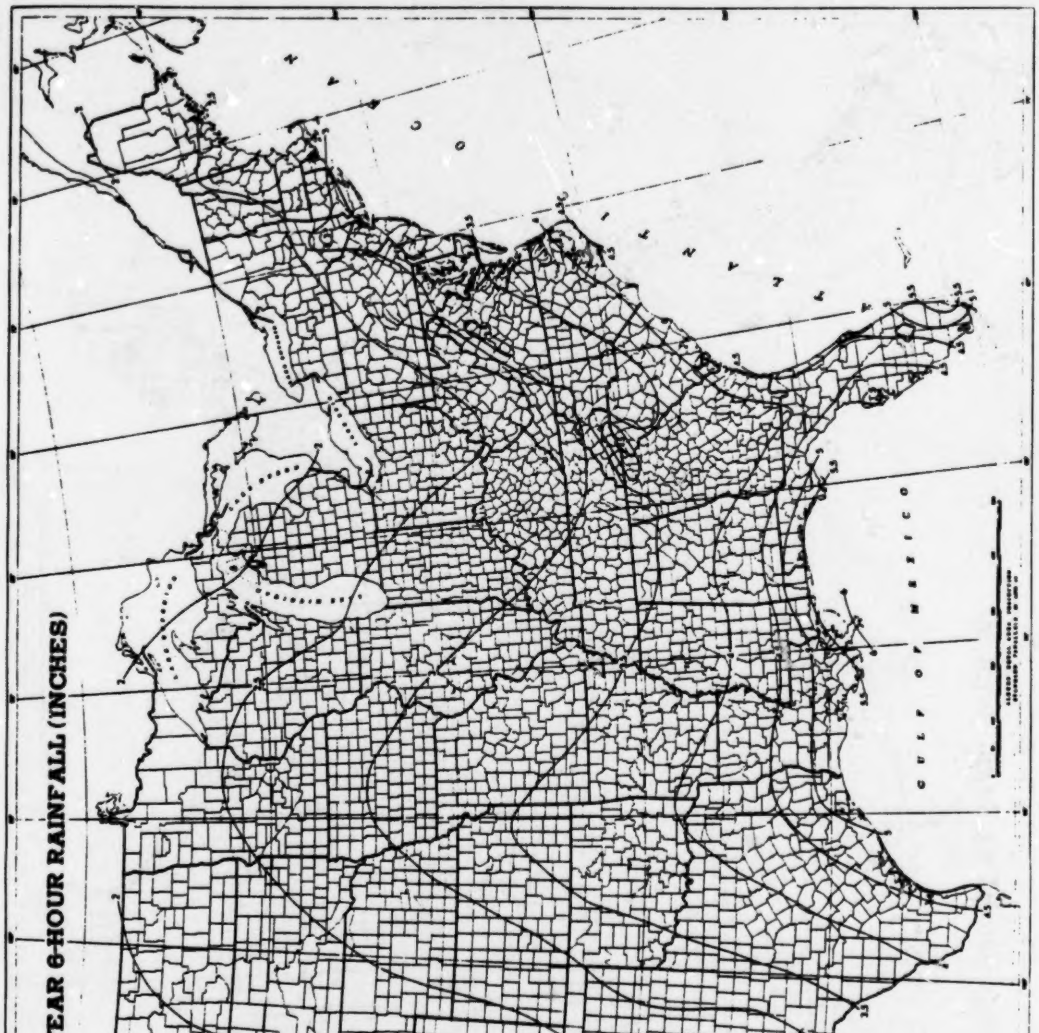


PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
.75
1
1.25
1.5
1.75
2
2.5
3



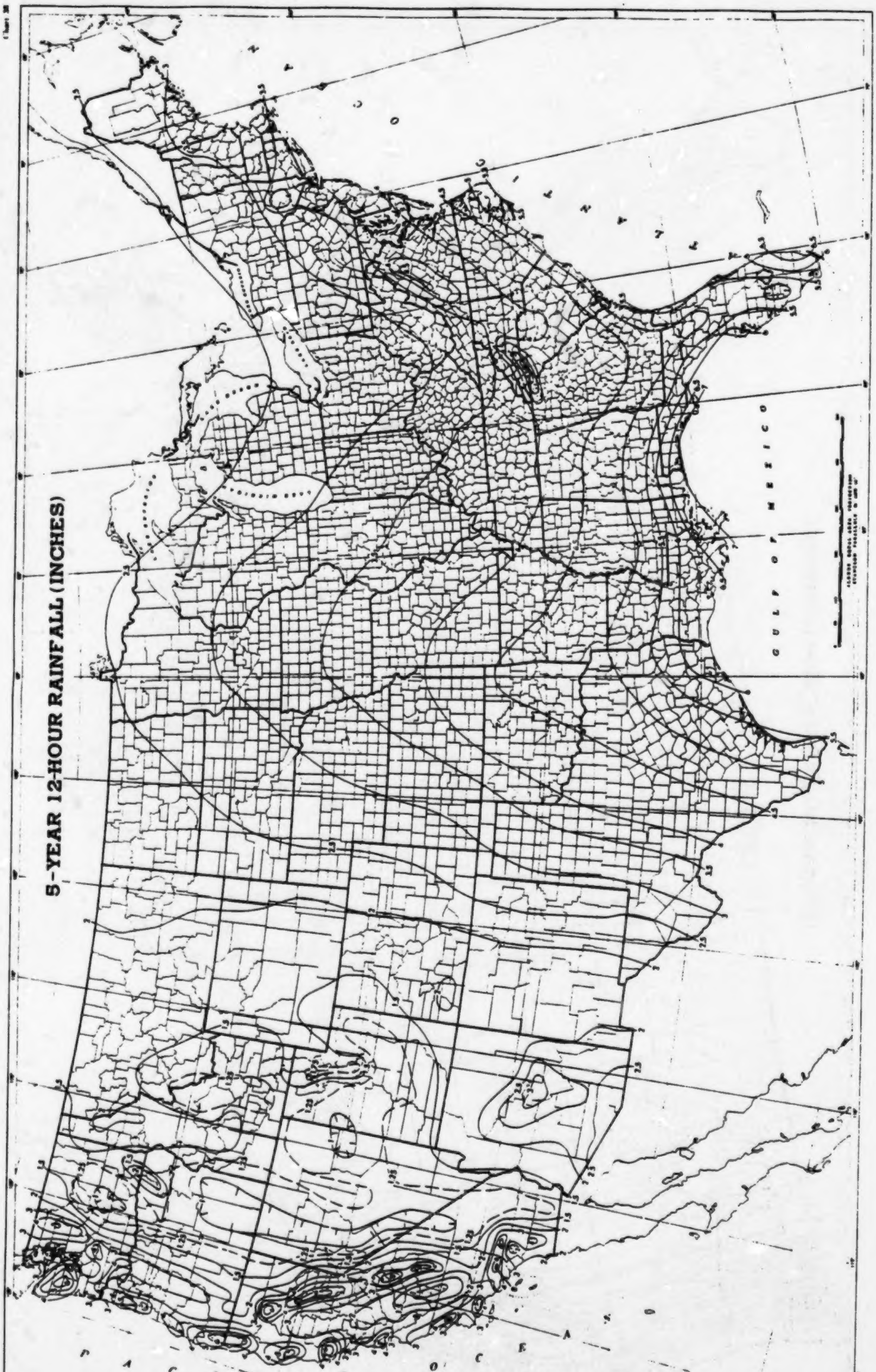
5-YEAR 3-HOUR RAINFALL (INCHES)

P A C I F I C O C E A N
A T L A N T I C O C E A N
G U L F O F M E X I C O
31



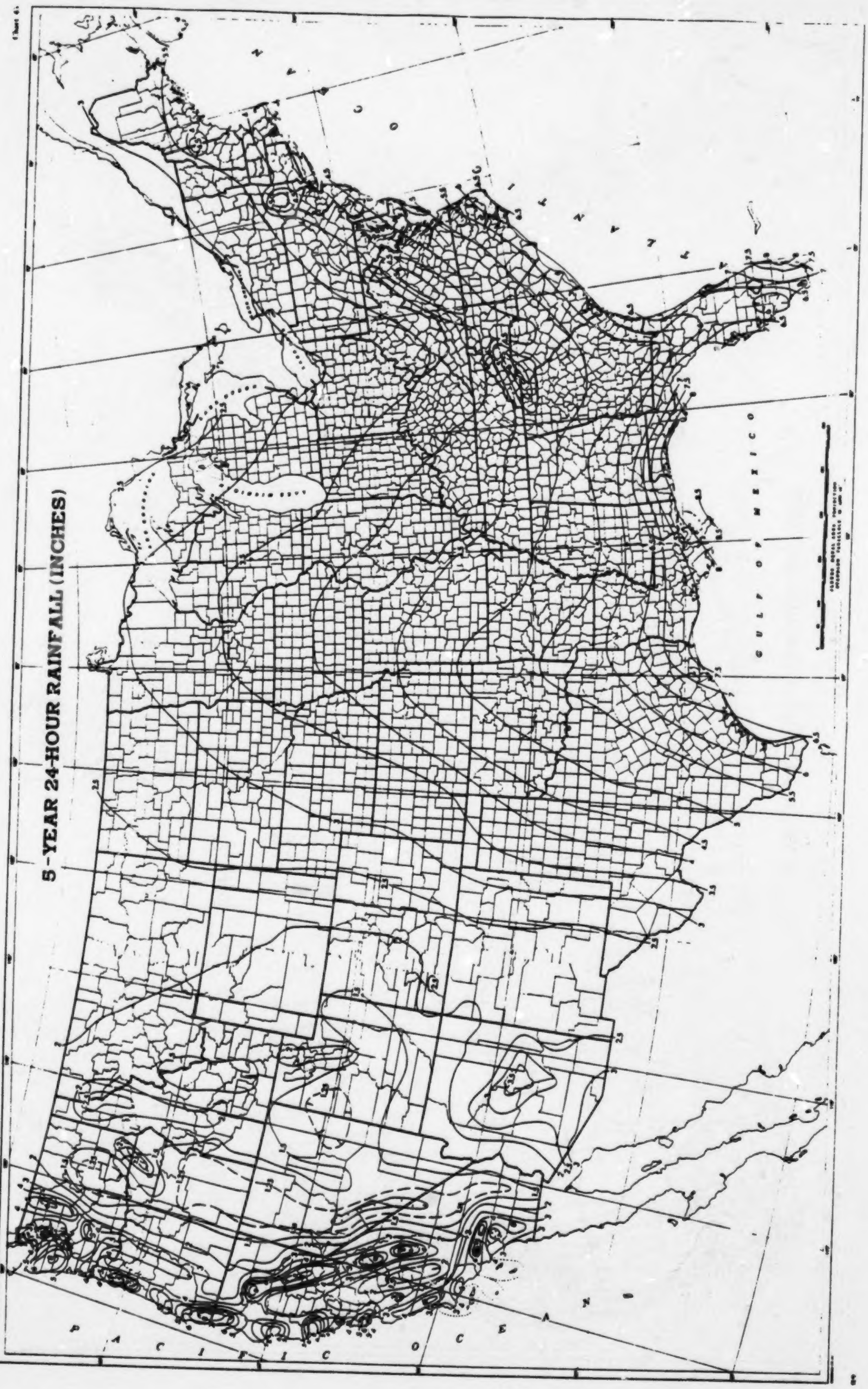
5-YEAR 6-HOUR RAINFALL (INCHES)

PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO



5-YEAR 12-HOUR RAINFALL (INCHES)

GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN



5-YEAR 24-HOUR RAINFALL (INCHES)

ATLANTIC OCEAN
GULF OF MEXICO
PACIFIC OCEAN

APPENDIX 4

PROCEDURE FOR INCORPORATING SITE-SPECIFIC CONSIDERATIONS IN RECEIVING WATER ANALYSES

As noted in Chapter 6, the procedure for selecting best management practices and regulatory limits is based on complete dilution of the contaminant load into the volumetric flow during the period of interest. However, applicants may feel that site-specific features will provide sufficient mitigation to warrant direct consideration. The following procedure is provided for those occasions.

A4.1. ASSUMPTIONS IN RECEIVING WATER PROCEDURE

This section describes assumptions that simplify the system (i.e., geometry) in order to obtain analytic solutions and assumptions regarding the processes and their parameterization. When appropriate, the effect of the assumption on the results is discussed. Major assumptions and ramifications are also included in Table A4-1.

A4.1.1. Streams. Stream geometry is simplified to accomodate use of analytic solutions. In the analysis, the stream channel is assumed to be uniform along the channel. This is a common assumption for river reaches. Where it is not valid, average values may be used.

Streamflow is assumed constant for event loadings and equals the average flow computed from the streamflow hydrograph. If the user is in doubt regarding the appropriate value of flow to use, lower estimates of flow reduce dilution and therefore lead to more conservative results (i.e., higher concentrations). Tributary inflows are also neglected, resulting, for the same reason, in more conservative results. Water depth is assumed constant. Because settling is an important removal process that is depth-dependent, when in doubt it is preferable to choose a larger depth.

Loading rate is assumed constant for the long-term analysis. For event loadings, only the total load is important and this should be overestimated

TABLE A4-1

Key Assumptions in Receiving Water Methodologies

Functional Area	Assumption	Ramification
All receiving waters (downstream area)	No transformation (decay) processes	Overpredicts to extent that transformations are important.
Streams		
Near Field (source area)	Complete mixing	Underpredicts water column concentration to extent that complete mixing is not achieved.
		Overpredicts water column concentration to extent that contaminant settles to bed.
	For constant loading and event cases (1, 2), bed concentration is constant and equal to loading concentration.	Overpredicts water column concentration because assumption maximizes bed concentration that acts as a source of contaminant to the water.
Estuary	Vertically and laterally well mixed	Underpredicts water column concentrations, especially near the loading.
	Steady state (tidal average)	Underpredicts instantaneous water column concentrations.
	Constant chemical concentration in bed	Tends to overpredict water column concentrations because it maximizes bed chemical concentrations and transport from bed to water column.
Lake	Completely mixed	Underpredicts water column concentrations to extent that vertical and/or lateral variations in water quality exist.

if in doubt. The runoff flow is assumed small relative to the streamflow and is neglected in estimating dilution. This assumption is therefore conservative.

Upstream sources are neglected because there is no convenient way to estimate upstream concentrations. Therefore, the results of the analysis are best viewed as relative to background or upstream values. The effect of upstream sources can be taken into account in an arbitrary way by reducing the criteria level.

Complete and instantaneous vertical and lateral mixing is assumed. This is most appropriate to relatively narrow and shallow streams. Equations to predict the length of channel (and therefore the time) required to achieve complete vertical and lateral mixing for a bank discharge are given in Fischer et al. (1979). Complete vertical mixing is often valid except very near the source, however, complete lateral mixing in wide rivers may take days, during which other processes may greatly reduce the amount of chemical in the river. If this is the case, the user should select an analytic "plume model," which describes downstream advection and lateral dispersion in rivers (Fischer et al., 1979).

The adsorption/desorption process is assumed to achieve instantaneous equilibrium. That equilibrium is described by the linear isotherm where the proportionality constant is the distribution coefficient. The ramifications of this model have been previously discussed.

Settling is estimated using Stokes' Law. The particle size distribution is characterized by the median grain size. It is conservative to select a smaller median grain size. Hindered settling and flocculation are neglected.

Conditions in the bed are assumed to be uniform except for a thin diffusive sublayer adjacent to the interface. Moreover, the concentration in the bed is specified a priori and is unaffected by settling, resuspension, or dissolved transport. (The one exception is Streams, Case 3 where bed concentrations decrease because of dissolved transport into the water column.) This assumption is made to obtain an analytic solution, is obviously invalid in the prototype, and violates mass conservation of chemical. The assumption is mitigated in that the bed concentration is selected to yield conservative (i.e., higher) estimates of water column concentrations. The bed is also assumed to be stationary, i.e., there is no allowance for bed load transport. The boundary between the water column and the bed is assumed to be distinct, i.e., there is no provision for a flocculant layer. Dissolved transport across the bed-water interface is assumed to be limited by resistance in the bed layer rather than in the water column. If particulate transport from the bed is considered, the procedure uses a resuspension velocity approach.

A4.1.2. Estuaries. A principal assumption in the analysis is that the estuary can be assumed to be one-dimensional, i.e., vertically and laterally well mixed. In particular, vertical stratification, which inhibits vertical mixing, is often found in estuaries. Estuaries are classified as well mixed, partially stratified, or stratified (salt wedge). The degree of stratification depends on the effect of freshwater inflow at the head of the estuary compared with turbulent mixing created by tidal and other forces. Since these factors vary temporally and spatially, stratification does also.

Estuaries are often complex topographically, and may include such features as multiple channels, islands, and bays. Moreover, the width of an estuary may vary significantly. Thus, the assumption of uniform width is unlikely to be satisfied in the general case, though it may be a good approximation for estuaries which are the result of drowned river valleys, or for sloughs.

In the model, the system is approximated as steady state by representing tidal average conditions. This means that velocity and water depth variations caused by tidal motion are neglected and the solution represents the average concentration that would be estimated from the actual time varying concentrations over a tidal cycle. Tidal effects on dispersion are incorporated implicitly in the selection of the dispersion coefficient (assumed constant) which in turn may be estimated from the longitudinal salinity gradient. The theoretical basis of a constant dispersion coefficient representing tidal average conditions is questioned by Fischer et al. (1979) who concluded that the tidal average advective-diffusion equation should be considered empirical.

In conclusion, the tidal average one-dimensional model is a relatively simple analytical tool that can, under proper circumstances, provide useful estimates, especially if inputs are selected to yield conservative results. Nonetheless, for many situations where an estuary is complex topographically, or stratified, the method is not appropriate and a simple analytic solution is unavailable.

A4.1.3. Lakes. The principal assumption involved in the lakes methodology is that the system is completely mixed. This assumption is generally not valid when the lake becomes vertically stratified (usually a seasonal phenomenon) or if the lake is elongated (i.e., "run of the river" type impoundments) and exhibits longitudinal variations in water quality. In some instances it may be warranted to consider only a portion of the lake as well-mixed. Guidance for such a decision is provided by viewing the vertical temperature profiles and tracking the development and vertical migration of the thermocline.

A4.2. RECEIVING WATER METHODOLOGY

A4.2.1. Loading Types. Analytic methods (following the work of O'Connor and Mueller, 1981) are presented for estimating concentrations of solids and chemicals in streams, lakes and estuaries caused by runoff and erosion from sludge land application areas. While storms are event occurrences, cumulative chronic effects on human health and aquatic life are important. In the context of analytic methods, such effects can be estimated assuming a constant mean loading rate (total mass of chemical released into the receiving water divided by the period over which the chemical was released). For lakes and estuaries, where mean residence times are large compared with streams, and accumulation of contaminants are of primary concern, constant loading is assumed. In streams, three cases may be considered: constant loading, event loading and event loading on large rivers where streamflow is high and unaffected by the storm event.

A4.2.2. Governing Equations and Their Solution. The set of equations governing toxic chemical fate in receiving waters is relatively complex. Because of adsorption and desorption, the chemical transport equation is linked to the solids transport equation. In principle, the solids transport equation is solved first and the solution is then input into the chemical transport equation. Unfortunately, analytic solutions to the chemical transport equation are usually only available for cases where the solids distribution is constant. Thus, it is common to approximate the solids distribution as a constant in order to proceed to an analytic solution of the chemical transport equation. Alternatives that require numerical schemes are available and discussed.

Where the bed of sediments underlying the water column serves as a source of solids and chemicals (i.e., through resuspension) one obtains a coupled set of equations governing the solids distribution and a coupled set of equations governing the chemical distribution. Coupled differential equations can be solved numerically, but are generally difficult to solve analytically. To obtain analytic solutions, assumptions are sometimes necessary to decouple the equations.

The methodology described below emphasizes the results and pertinent assumptions. Many of the steps used in developing and solving the governing equations subject to initial and boundary condition are left out. Although the exact form of the solutions may differ, the interested reader may refer to O'Connor and Mueller (1981) to gain an appreciation for the procedure by which the governing equations are developed.

A4.2.3. Nomenclature and Some Basic Relationships. Figure A4-1 shows a definition sketch. Variables in the water column are identified by subscript 1, bed variables by subscript 2. For example, the water depth is H_1, the contaminated bed depth is H_2. The solids loading, if continuous, is E, which has units of mass (M) per unit time (T); if the loading is an event loading, it will be designated E_0, which has units of mass (M) and represents the total solids mass entering the receiving water over the duration of the event. The same scheme is used for the chemical loading designated by M or M_0. The chemical load is the sum of the dissolved and adsorbed contributions.

The concentration of the solids in the water column is given as m_1 (M/L^3) and in the bed $m_2(M/L^3)$. M is unit of mass, L is unit of length and L^3 is unit of volume. These are unspecified general units. The bed solids concentration is the bulk density given by

$$m_2 = B\,(1 - \theta) \qquad (M/L^3) \qquad \text{(A4-1)}$$

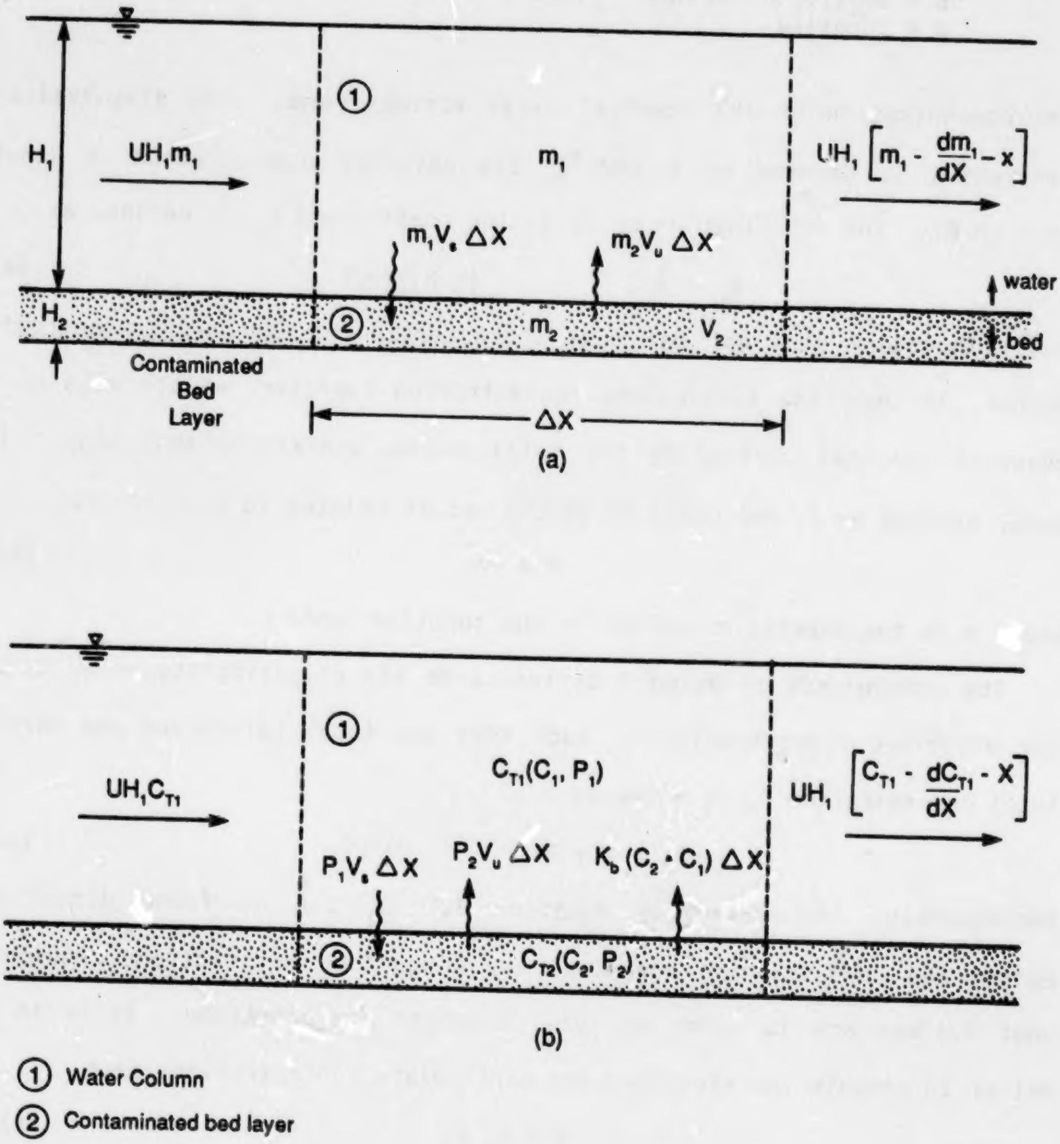

H₁
UH₁m₁
①
m₁
UH₁ [m₁ - dm₁/dX - x]
m₁Vₛ ΔX
m₂Vᵤ ΔX
water
H₂
②
m₂
V₂
bed
Contaminated Bed Layer
ΔX
(a)
①
C_T1(C₁, P₁)
UH₁C_T1
UH₁ [C_T1 - dC_T1/dX - X]
P₁Vₛ ΔX
P₂Vᵤ ΔX
K_b (C₂ - C₁) ΔX
②
C_T2(C₂, P₂)
(b)
① Water Column
② Contaminated bed layer

FIGURE A4-1

Definition Sketch for Developing Governing Equations for Constant Loading into Stream: (a) Solids, (b) Chemicals

where

B = density of solids (M/L³)
Θ = porosity

The concentration of the chemical takes various forms. The dissolved concentration is denoted as C (M/L^3), the adsorbed concentration is denoted as r (M/M). The distribution or partition coefficient k_d is defined as

$$k_d = r/C \qquad (M/M)/(M/L^3) \tag{A4-2}$$

The methodology does not use r to characterize the adsorbed concentration. Rather, it uses the particulate concentration expressed as the mass of the adsorbed chemical divided by the total volume containing that mass. This term, denoted by P, has units of (M/L^3) and is related to r as follows:

$$P = rm \tag{A4-3}$$

where m is the density of solids in the sorption system.

The convenience of using P derives from its compatibility in units with the dissolved concentration C, such that the total (dissolved and particulate) concentration C_T is given as

$$C_T = C + P \qquad (M/L^3) \tag{A4-4}$$

Consequently, the governing equation for C_T can be found directly by adding the corresponding equations for P and C. The solutions provided in what follows are in terms of total chemical concentration. It is an easy matter to compute the dissolved and particulate concentrations from

$$C = f_d\, C_T \tag{A4-5}$$

$$P = f_p\, C_T \tag{A4-6}$$

where f_d is the dissolved fraction

$$f_d = 1/(1 + k_d m) \tag{A4-7}$$

and f_p is the particulate fraction

$$f_p = (k_d m)/(1 + k_d m) \tag{A4-8}$$

and

$$f_p + f_d = 1 \qquad \text{(A4-9)}$$

Figure A4-2 shows how the dissolved and adsorbed fractions vary with $k_d m$, a convenient unitless parameter to describe the partitioning.

Transport mechanisms such as settling are expressed as $m_1 V_s$ (M/L^2T) where V_s is the settling velocity. The effect of settling and other transport processes are often characterized through a rate coefficient as follows:

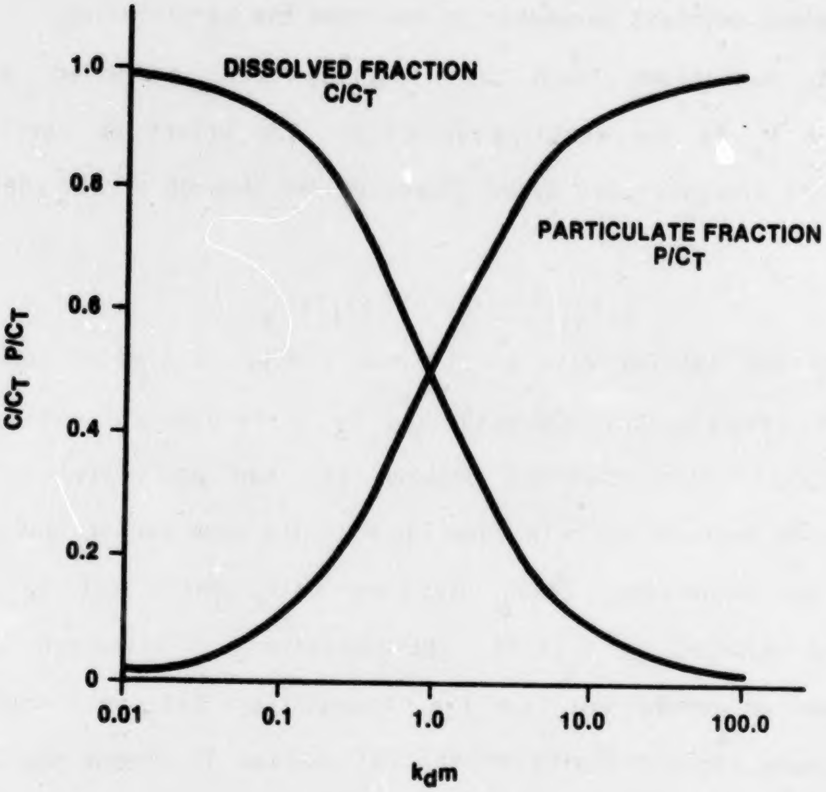
$$K_{s1} \overset{\Delta}{=} V_s/H_1 \qquad (1/T) \qquad \text{(A4-10)}$$

where K_{s1} is the setting rate coefficient (1/T). A similar approach is followed for resuspension, characterized by a resuspension velocity V_u. Transport of dissolved chemical between the bed and water column is expressed by an engineering rate equation with the rate coefficient given as K_b'(L/T). The methodology often uses the rate coefficient K_b' divided by the depth denoted by K_b(1/T). Resuspension and dissolved transport across the bed of contaminant from the streambed are not considered in this analysis because the difficulty of the calculation is beyond the scope of this document.

A list of commonly occurring nomenclature is given in Table A4-2 for easy reference.

A4.2.4. Streams.

A4.2.4.1. CASES CONSIDERED -- Two cases were considered corresponding to those time scales that were felt to be potentially important (Figure A4-3). Case 1 corresponds to the constant mean loading equal to the total loading from the various events divided by the time period of interest. This case provides an estimate of chronic exposure levels. Case 2 corresponds to the period during the rainfall/runoff event.



NOTE: FIGURE IS FOR CONSTANT VALUE OF k_d

SOURCE: O'CONNER AND MUELLER, EDITORS
MANHATTAN COLLEGE
NOTES ON MODELING TOXIC SUBSTANCES
1981

FIGURE A4-2

Equilibrium Concentrations of Dissolved and Particulate Toxicant as a Function of $K_d m$

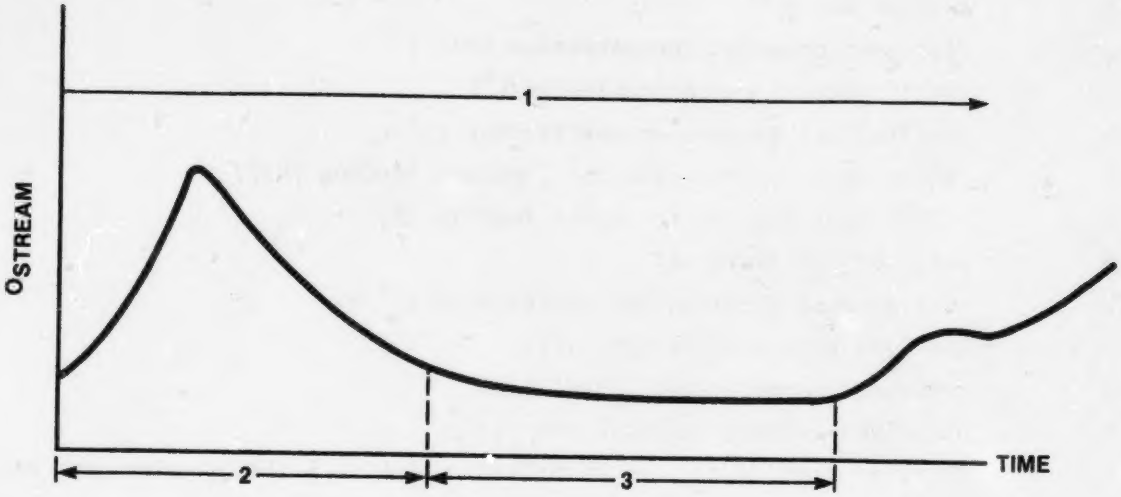
TABLE A4-2

Selected Nomenclature for Receiving Water Analysis*

A	area of bed (L^2)
C	dissolved chemical concentration (M/L^3)
C_T	total chemical concentration (M/L^3)
D	longitudinal dispersion coefficient (L^2/L)
E	solids mass loading rate for constant loading (M/T)
E_o	solids mass loading for event loading (M)
H	water or bed depth (L)
K_d	partition or distribution coefficient (L^3/M)
K_s	settling rate coefficient (1/T)
K_u	resuspension rate coefficient (1/T)
K_b	dissolved exchange coefficient (1/T)
K_b'	transfer coefficient of dissolved chemical between water and bed (L/T)
m	solids concentration (M/L^3)
M	chemical mass loading (for constant loading) (M/T)
M_o	chemical mass loading (for event loading) (M)
P	particulate chemical concentration (M/L^3)
Q	flowrate (L^3/T)
r	adsorbed chemical concentration (M/M)
U	current speed (L/T)
V	volume (L^3)
V_s	settling velocity (L/T)
V_u	resuspension velocity (L/T)
V_d	sedimentation velocity (L/T)
B	solids density (M/L^3)
θ	porosity
WD	watershed dilution
WS	area of watershed (L^2)
x	distance downstream (L)

---

*M, L, T, L^2 and L^3 denote unspecified units of mass, length, time, area and volume, respectively.



CASE	PERIOD OF INTEREST	STREAM-FLOW	SOURCE
1		MEAN	EROSION
2	DURING EVENT	HIGH	RUNOFF/ EROSION
3	FOLLOWING EVENT	LOW	CONTAMINATED BOTTOM SEDIMENTS

FIGURE A4-3

Time Scales and Cases Considered in Stream Analysis

A4.2.4.2. CONSTANT LOADING (CASE 1) -- Since dispersion effects are integrated away for steady transport problems, the transport equation may be simplified to this equation:

$$\frac{dC_{Ti}}{dx} = -K_iC_{Ti} \qquad \text{(A4-11)}$$

where K_i is a combined dilution/settling rate constant given by

$$K_i = \frac{K_{si}}{U} + 1/WD \qquad \text{(A4-12)}$$

K_{si} is the net settling/resuspension constant from equation A4-10 and WD is a dilution parameter that is characteristic of the watershed.

Schematically, the watershed is represented as in Figure A4-4. The stream contamination concentration is assumed to be diluted by the factor

$$\frac{WS(o)}{WS(x)} \qquad \text{(A4-13)}$$

where WS(x) is the watershed area for a position located distance x downstream from the SMA boundary. Equation A4-13 does not include settling or resuspension effects.

Letting D^2 denote the watershed area at position x=0,

$$D^2 = WS(o) \qquad \text{(A4-14)}$$

equation A4-13 becomes:

$$\frac{D^2}{(x+WD)^2} = \frac{1}{(1+\frac{x}{WD})^2} \simeq \exp(-\frac{x}{WD}) \qquad \text{(A4-15)}$$

Solving equation A4-11 yields the solution:

$$C_{Ti}(x) = C_{Ti}(o)\ \exp - \frac{K_{si}}{U} + \frac{1}{WD}\ x \qquad \text{(A4-16)}$$

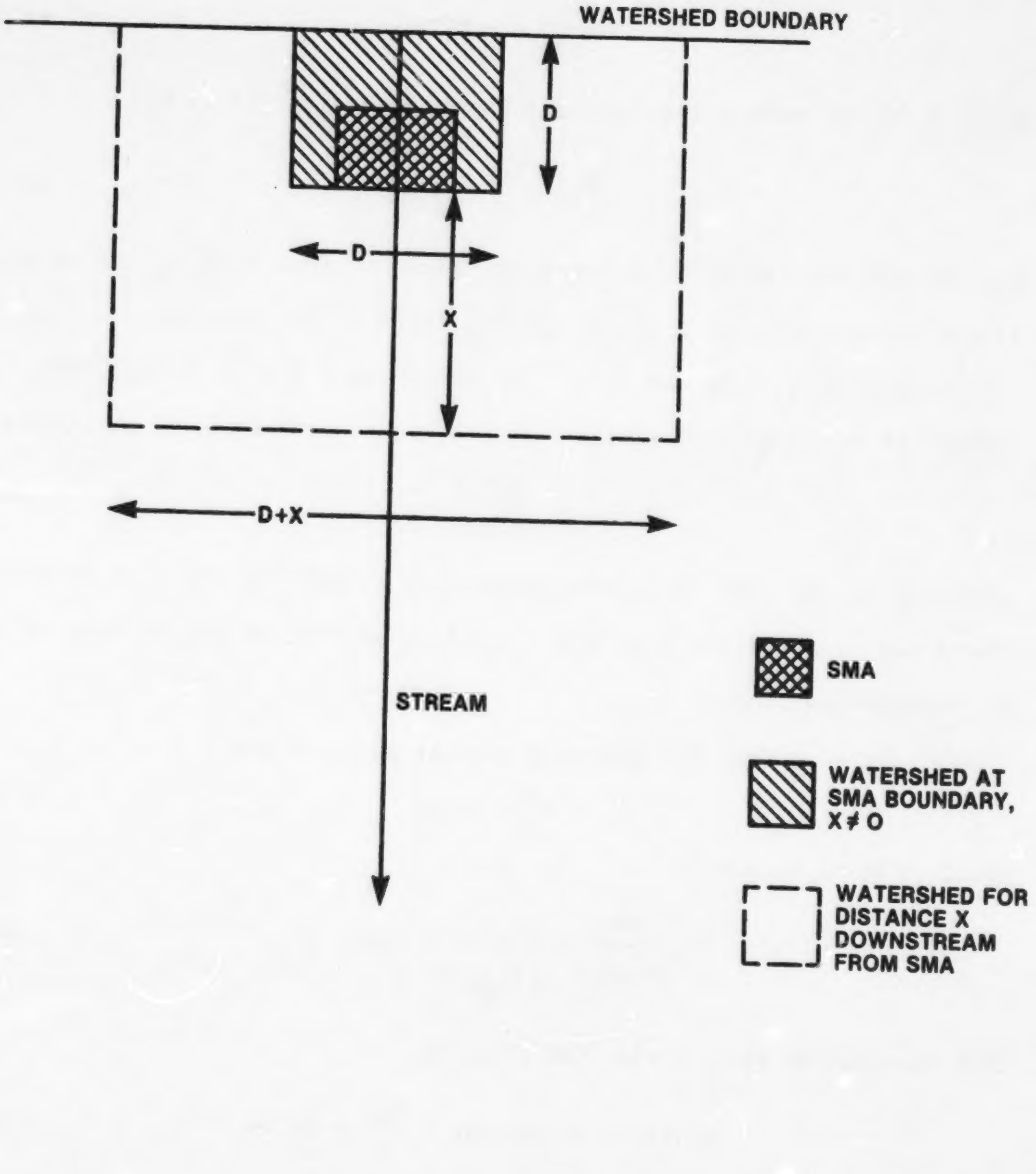

WATERSHED BOUNDARY
D
D
X
D+X
STREAM
SMA
WATERSHED AT SMA BOUNDARY, X ≠ O
WATERSHED FOR DISTANCE X DOWNSTREAM FROM SMA

FIGURE A4-4

Schematic Representation of Watershed
(not to scale)

The concentration boundary conditions at x=0, based on complete mixing of the discharge over the stream cross-section, are as follows:

solids $m_o = E/Q$ (A4-17)

chemical $C_{T1,o} = M/Q$ (A4-18)

where E and M are the solids and chemical loading rates and Q is the streamflow.

The governing equation for solids in the water column based on conservation of mass applied to the differential element in Figure A4-1 is

$$0 = -H_1 U \frac{dm_1}{dx} - V_s m_1 \tag{A4-19}$$

Dividing by H_1 and rearranging,

$$U \frac{dm_1}{dx} + K_{s1} m_1 = 0 \tag{A4-20}$$

the solution, subject to the boundary condition at x=0, is

$$m_1 = m_o \exp(-K_{s1} x/U) \tag{A4-21}$$

The methodology can be used in a tiered manner. The Tier 1 result is the well mixed concentration given by equation A4-18. If the receptor is downstream, the Tier 2 result is obtained from equation A4-16 with inputs from the literature. Site specific inputs can be obtained if a Tier 3 analysis is warranted.

A4.2.4.3. EVENT LOADING (CASE 2) -- Figure A4-5 shows the time changes in the concentration distribution resulting from an event loading into a stream. In this case, it is assumed that the total mass of solids and chemical is initially completely mixed in a volume of water equal to the streamflow times the duration of the event. Subsequent to this initial mixing, the contaminated volume is advected downstream where settling, resuspension, dissolved transport across the bed, and longitudinal dispersion takes place. For simplicity of calculation and because many of the

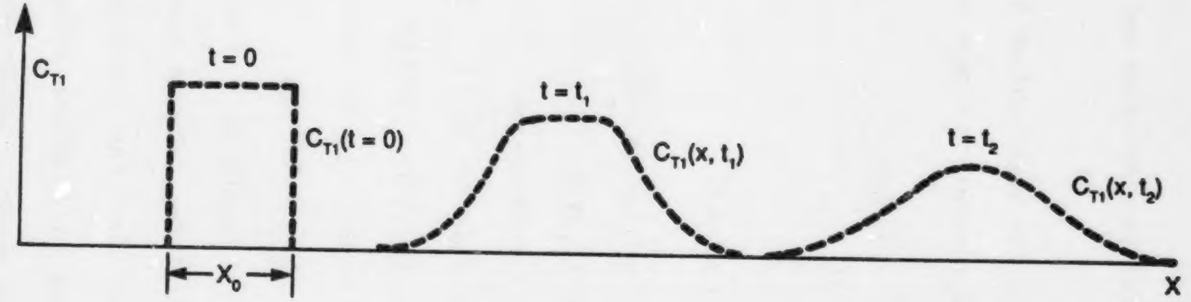

C_{T1}
t = 0
$C_{T1}(t = 0)$
X_0
t = t_1
$C_{T1}(x, t_1)$
t = t_2
$C_{T1}(x, t_2)$
X

FIGURE A4-5

Sketch of Solution for Event Loading in Stream (Case 2) parameters are not easily estimated, resuspension and dissolved transport are not calculated for the event loading case, just as they were not calculated for the long-term averaging case.

The initial mixed concentrations, estimated assuming that the event load is completely mixed throughout the volume, are as follows:

solids $$m_o = E_o/V_1 \tag{A4-22}$$

chemical $$C_{T1,o} = M_o/V_1 \tag{A4-23}$$

where V_1 is the volume of the completely mixed cell, E_o is the mass of all solids entering the stream, M_o is the mass of dissolved phase plus adsorbed contaminant entering the stream for the event case. The length of the cell X is

$$X = U\Delta T \tag{A4-24}$$

where

U = current speed
ΔT = duration of the loading event

The governing equations for the solids and total chemical in the water column are

solids

$$\frac{\partial m_1}{\partial t} + U \frac{\partial m_1}{\partial x} - D \frac{\partial^2 {}_1}{\partial x^2} + K_{s1} m_1 = 0 \tag{A4-25}$$

chemical

$$\frac{\partial C_{T1}}{\partial t} + U \frac{\partial C_{T1}}{\partial x} - D \frac{\partial^2 C_{T1}}{\partial x^2} + K_{s1} + 1/D = 0 \tag{A4-26}$$

where D is the longitudinal dispersion coefficient.

The solutions for the solids and chemical as a function of x and t, where x is the distance downstream and t is time, are shown below:

solids

$$m_1(x,t) = m_o \exp^{-k_{s1}t} \tag{A4-27}$$

chemical

$$C_{T1}(x,t) = C_{T1,o} \exp^{-k_1 t} \tag{A4-28}$$

where

$$K_1 \overset{\Delta}{=} K_{s1} + 1/D \tag{A4-29}$$

(for many cases involving resuspension of chemicals with high partition coefficients (≥ 100) it is sufficiently accurate to assume that $f_{p2} \sim 1$, $f_{d2} \sim 0$; then $K_2 \rightarrow K_{u1}$)

If only the maximum concentrations are of interest, equations A4-27 and A4-28 can be evaluated at $t' = x/U$, yielding

maximum solids conc.

$$m_{1,max} = m_o \exp^{-K_1 t'} \tag{A4-30}$$

maximum chemical conc.

$$C_{T1,max} = C_{T1,o} \exp^{-K_1 t'} \tag{A4-31}$$

The Tier 1 result is given by equation A4-23. The Tier 2 analysis based on equation A4-31 for maximum chemical concentration can be applied if the receptor is downstream of the loading. Input values from the literature are chosen for the Tier 2 analysis, whereas site-specific inputs can be developed if a Tier 3 analysis is deemed warranted.

A4.2.5. Lakes. For lakes the critical issue is often the accumulation of chemicals over time, especially in the sediments. For this reason the analysis considers constant loading. Figures A4-6a and A4-6b show the definition sketch for the analysis. Settling and resuspension are considered.

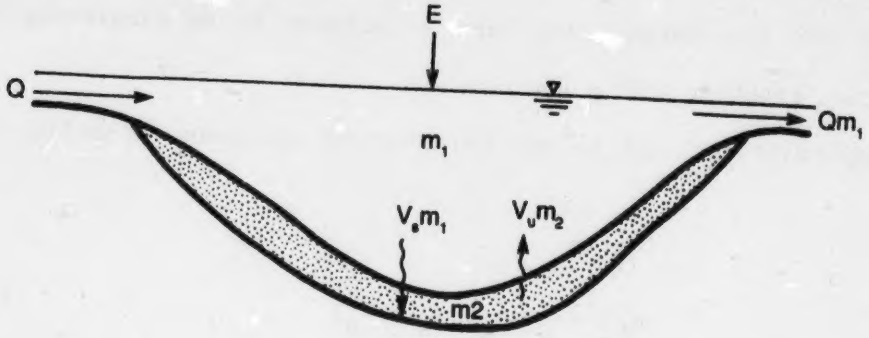

E
Q
Qm$_1$
m$_1$
V$_s$m$_1$
V$_u$m$_2$
m2

FIGURE A4-6a

Definition Sketch for Lake Analysis: Solids

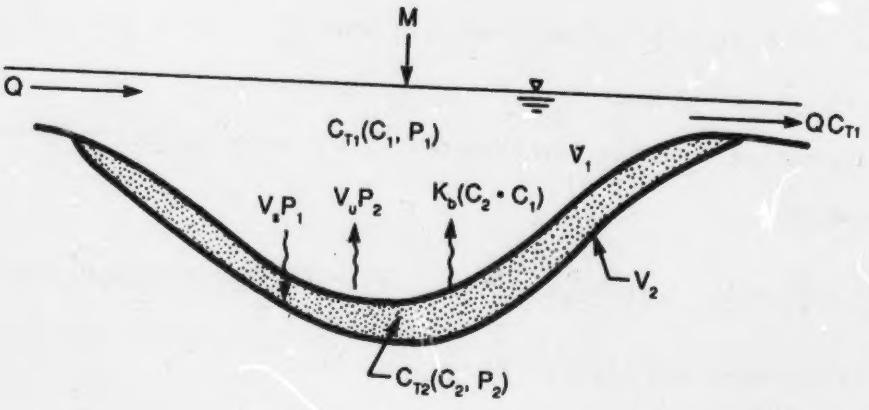

M
Q
QC$_{T1}$
C$_{T1}$(C$_1$, P$_1$)
V$_1$
V$_s$P$_1$
V$_u$P$_2$
K$_b$(C$_2$ • C$_1$)
V$_2$
C$_{T2}$(C$_2$, P$_2$)

FIGURE A4-6b

Definition Sketch for Lake Analysis: Chemicals

Dissolved transport between the bed and the water column is negligible and therefore was not considered. The lake is assumed to be completely mixed and subject to a constant inflow and outflow.

The steady-state solution to the conservation equations for solids is as follows:

bed

$$m_2 = (m_1 \; V_s)/(V_u + V_d) \qquad \text{(A4-32)}$$

water column

$$m_1 = (E/V_1)/(1/t_o + \beta K_{s1}) \qquad \text{(A4-33)}$$

where

$V_d = dH_2/dt$ (sedimentation velocity) (A4-34)

$t_o = V_1/Q$ (mean residence time in the lake) (A4-35)

$\beta \overset{\Delta}{=} V_d/(V_u + V_d) \sim 1$ (A4-36)

and V_1 = the volume of the lake (ℓ).

The sedimentation velocity is the rate of change in bed thickness caused by the net effect of resuspension and settling and therefore may be positive or negative. The term β varies from zero when $V_d = 0$ (no net solids flux across interface) to one when $V_u = 0$ (no resuspension).

The conservation equation for chemical in the water column is given by

water column

$$\frac{dC_{T1}}{dt} = \frac{M}{V_1} - \left[\frac{1}{t_o} + f_{p1}K_{s1} + f_{d1}K_{b1}\right] C_{T1} + \left[f_{p2}K_{u1} + f_{d2}K_{b1}\right] C_{T2} \qquad \text{(A4-37)}$$

where the terms represent the following processes:

$\frac{M}{V_1}$ = loading

$\frac{1}{t_o}$ = advection

$f_{p1}K_{s1}$ = settling

$f_{d1}K_{b1}$ = dissolved transport from water column to bed

$f_{p2}K_{u1}$ = resuspension

$f_{d2}K_{b1}$ = dissolved transport from bed to water column

(A similar equation applies to the chemical in the bed.) At steady state

$$\frac{dC_{T1}}{dt} = \frac{dC_{T2}}{dt} = 0 \qquad \text{(A4-38)}$$

and the solution to the conservation equations for chemical are:

water column

$$C_{T1} = (M/V_1)/(K_1 - (K_2K_3)/K_4) \qquad \text{(A4-39)}$$

bed

$$C_{T2} = (K_3/K_4)\ C_{T1} \qquad \text{(A4-40)}$$

where

$$K_1 = 1/t_o + f_{p1}K_{s1} + f_{d1}K_{b1} \qquad \text{(A4-41)}$$

$$K_2 = f_{p2}K_{u1} + f_{d2}K_{b1} \qquad \text{(A4-42)}$$

$$K_3 = f_{p1}K_{s2} + f_{d1}K_{b2} \qquad \text{(A4-43)}$$

$$K_4 = f_{p2}(K_{u2} + K_{d2}) + f_{d2}K_{b2} \qquad \text{(A4-44)}$$

In lakes it is often feasible to neglect resuspension (V_u=0), in which case, as discussed previously, ß reduces to 1. Equations A4-32, A4-33, A4-39 and A4-40 simplify as follows:

solids

water column $$m_1 = (E/V_1)/(1/t_o + K_{s1}) \qquad \text{(A4-45)}$$

bed $$m_2 = (V_s/V_d)\ m_1 \qquad \text{(A4-46)}$$

chemical

water column $$C_{T1} = \frac{M/V_1}{K_1 - (f_{d2}K_{b1}K_3)/(f_{p2}K_{d2} + f_{d2}K_{b2})} \qquad \text{(A4-47)}$$

bed $$C_{T2} = K_3C_{T1}/(f_{p2}K_{d2} + f_{d2}K_{b2}) \qquad \text{(A4-48)}$$

Another simplified solution is obtained if the mass solids concentration in the bed and the partition coefficient in the bed are sufficiently large such that $k_{d2}m_2 >> 1$. Then $f_{p2} \sim 1$ and $f_{d2} \sim 0$ and equations A4-39 and A4-40 simplify to the following:

$$C_{T1} = \frac{M/V_1}{1/t_o + \beta(f_{p1}K_{s1})} \qquad \text{(A4-49)}$$

$$C_{T2} = \frac{(f_{p1}K_{s2} + f_{d1}K_{b2})\ C_{T1}}{K_{u2} + K_{d2}} \qquad \text{(A4-50)}$$

A convenient result for a Tier 1 type analysis is achieved if it is further assumed that there is no net solids flux across the sediment boundary (β=0). Then equation A4-49 reduces to

$$C_{T1} = (M/V_1)/(1/t_o) = M/Q \qquad \text{(A4-51)}$$

where Q_L is the sum of the outflows from the lake. Although this assumption is not likely to be valid in a quiescent lake, it does provide a conservative estimate suitable for the Tier 1 analysis. Equation A4-49 should be used for a Tier 2 and 3 analysis.

A4.2.6. Estuaries. The estuary analysis assumes one-dimensional, vertically well mixed conditions and seeks to obtain a steady state (tidal average) solution. The loading is assumed to be constant and occurs at x=0 (Figure A4-7). Processes include advection by the freshwater flow, longitudinal dispersion which takes into account tidal and other mixing processes, resuspension and settling, and dissolved transport across the bed.

The steady-state tidal average solutions for solids and chemical (O'Conner and Mueller, 1981; Fischer et al., 1979) are as follows:

solids

bed $\quad m_2 = V_s m_1/(V_u + V_d)$ (A4-52)

water column $\quad m_1 = E/Qn_s \exp[(Ux/2D)(1 \pm n_s)]$ (A4-53)

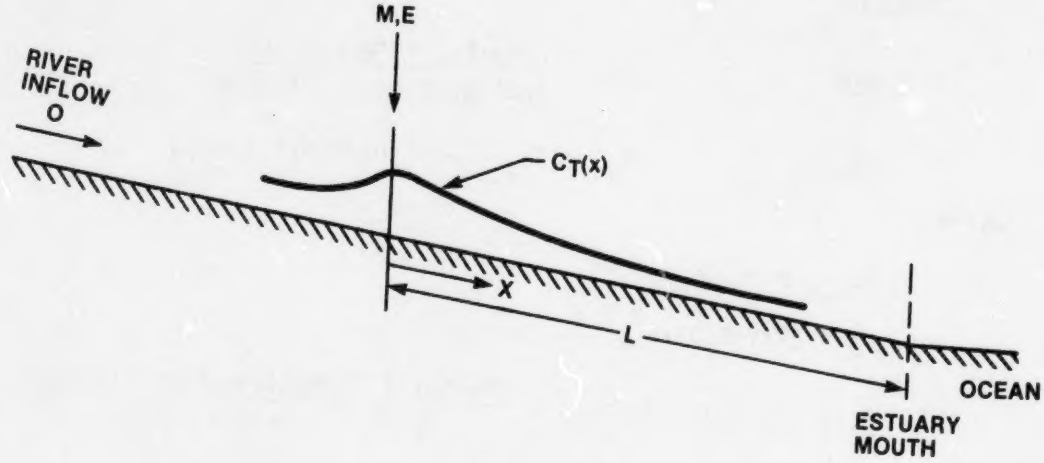

M,E
RIVER
INFLOW
Q
$C_T(x)$
X
L
ESTUARY
MOUTH
OCEAN

FIGURE A4-7

Graphical Representation of Solution for One-Dimensional Tidal Average Estuary Analysis

where

Q = freshwater inflow at head of estuary

U = net downstream velocity caused by freshwater discharge

$$n_s = (1+4(K_1D)/U^2)^{0.5} \tag{A4-54}$$

$$K_1 = K_{s1} + \alpha\, K_{u1} \tag{A4-55}$$

$$\alpha = V_s/(V_u + V_d) \tag{A4-56}$$

$$K_{u1} = V_u/H_1 \tag{A4-57}$$

chemical

bed

$$C_{T2} = \frac{[f_{p1}K_{s2} + f_{d1}K_{b2}]\; C_{T1}}{f_{p2}(K_{u2} + K_{d2}) + f_{d2}K_{b2}} \tag{A4-58}$$

water

$$C_{T1} = C_{T1,o}\; \exp[(Ux/2D)(1 \pm n_c)] \tag{A4-59}$$

where

$$C_{T1,o} = M/(Qn_c) \tag{A4-60}$$

$$n_c = (1+(4K_2D)/U^2)^{0.5}$$

$$K_2 = (f_{d1}K_{b1} + f_{p1}K_{s1}) + \frac{(f_{d2}K_{b1} + f_{p2}K_{u1})(f_{p1}K_{s2} + f_{d1}K_{b2})}{f_{p2}(K_{u2} + K_{d2}) + f_{d2}K_{b2}} \tag{A4-61}$$

$$K_{b1} = K_b'/H_1$$

It is important in using these equations to be aware of the sign convention. When downstream of the loading, x is positive and the sign of n chosen in equations A4-53 and A4-58 is negative. If upstream x is negative and the sign of n is positive, the result is that the concentration decreases more rapidly in the upstream direction as shown in Figure A4-7.

Fischer et al (1979) point out that equation A4-58 is invalid for the downstream portion if the loading is sufficiently close to the mouth of the estuary because it predicts the concentration of zero at infinity rather than at the estuary mouth. They provide the following correct solution.

$$C_{T1} = C_{T1,o}\,\frac{\exp[-(1-n_c)Ux/2D] - \exp[-(1+n_c)Ux/2D]}{\exp[-(1-n_c)UL/2D] - \exp[-(1+n_c)UL/2D]} \tag{A4-62}$$

where

$$CT1,o = \frac{M\,[1-\exp(-(UL/D)\,n_c)]}{Qn_c} \qquad \text{(A4-63)}$$

L = distance between loading and estuary mouth.

It should be noted that D is an equivalent tidal average dispersion coefficient which may be obtained from the mean longitudinal salinity gradient as follows:

$$D = \frac{Us}{\frac{\partial s}{\partial x}} \qquad \text{(A4-64)}$$

The Tier 1 result is given by equation A4-60. The higher levels of analysis should utilize equations A4-58 and A4-59 or A4-62.

A4.2.7. Protocol for Applications of the Receiving Water Methodology. This section provides guidance for selecting the inputs that tend to define the problem. A good example is selection of the appropriate value of streamflow from the streamflow record. A second category of inputs, that relate to processes (e.g., dispersion coefficients) have generally been the subject of research and values (or estimation techniques) are available in the literature. This second category of inputs is discussed in the data input section.

A4.2.7.1. FLOWS -- The stream methodology considers 3 cases, mean loading, event loading on small streams and event loading on large rivers where the flow is not greatly affected by the storm event. The streamflow selected for each case should be consistent with the criteria applied in developing the loading. Thus a mean annual streamflow should be used with a mean annual loading. For event loading, the level of the selected streamflow should agree with the hydrograph for the rainfall event used to generate the event loading. For case 3 a low streamflow is used if the receiving water is large and not greatly affected by the storm event. Low flows are often defined in terms of duration and recurrence interval. A popular choice for flow for dissolved oxygen problems is the 7Q10, which is the 7-day mean low flow having an average recurrence interval of 10 years. In this methodology, the selected duration for the flow should be consistent with the time scale associated with the release of chemical from the sediments. The recurrence interval of the low streamflow should be consistent with that of the preceding event. From a practical point of view, the user may wish to use the 7Q10 value because of its availability and because its use would tend to yield conservative estimates. It is unlikely that a runoff event large enough to create a serious benthic source would occur simultaneously with the period of 7Q10 flow.

In the estuary and lake methodologies, the mean annual flows consistent with the loading should be used.

A4.2.7.2. BED CONDITIONS -- In order to develop simple analytic solutions for the estuary and for Cases 1 and 2 in the streams analysis, the concentration of solids and chemical in the bed are assumed constant and are treated as boundary conditions. Therefore the bed concentration must be specified a priori. The mass solids concentration or bulk density is given by

$$m_2 = B\,(1-\theta) \qquad \text{(A4-65)}$$

where B is the solids density and θ the mean porosity.

The total chemical concentration C_{T2} in the bed cannot be estimated directly based on loading and conditions in the receiving water. Order-of-magnitude estimates of C_{T2} are possible by assuming that the adsorbed fraction in the bed equals the adsorbed fraction in the loading.

$$\text{i.e., } r_2 = r_L \qquad \text{(A4-66)}$$

where

r_2 = adsorbed fraction in bed (M/M)
r_L = adsorbed fraction in loading (M/M)

Then the total chemical concentration in the bed is

$$C_{T2} \sim r_2 m_2 = r_L m_2 \qquad (A4\text{-}67)$$

The estimate using this equation would tend to be conservative because it essentially assumes that all adsorbed chemical settles to the bed and that the loading is sufficient to establish this concentration over the bed volume of interest. Thus chemical mass is not conserved using this estimation technique. A more reasonable assumption is that bed sediments will reflect the sediments from all of the upflow watershed. Hence,

$$C_{T2} = \frac{SMA}{WS(x)} \qquad (A4\text{-}68)$$

where

SMA = area of the site (ha)

WS(x) = area of the watershed upflow of x, the point of interest (ha)

This is further illustrated in Figure A4-4.

In the case of lakes and Case 3, streams, the bed concentration is estimated as part of the solution so the above approximation is not required.

The depth of the contaminated bed is not required in any of the analyses except for lakes, where it enters in the more complex expressions for C_{T1} and C_{T2}. There is considerable uncertainty about the depth of the contaminated bed given the expected non-homogeniety of the bed sediments. If the user finds it necessary to estimate the depth of the contaminated bed, it seems the best available advice is to use an order-of-magnitude estimate. For example, the bed depth might be of the order of 10 cm as opposed to 1 cm or 100 cm. Site specific information would facilitate a choice.

A4.3. DATA INPUTS FOR RECEIVING WATER ANALYSIS -- Data inputs for the receiving water analysis may require:

- settling, resuspension, and sedimentation rate coefficients
- rate coefficient for dissolved transport across the bed
- longitudinal dispersion coefficients
- partition or distribution coefficients
- bed sediment properties

Guidance for selecting values of these inputs is provided below.

A4.3.1. Settling, Resuspension and Sedimentation Rate Coefficients. The sediment velocity scales are the settling velocity, resuspension velocity, and sedimentation velocity. These parameters are included in the analyses to reflect certain processes. However, because of the uncertainty in quantifying the process, values are often obtained through calibration. For example, a mean settling rate in a lake may be deduced by comparing inflow and outflow suspended solids. Available data from similar water bodies may also be used to estimate these parameters.

In lieu of available data, other approximation techniques are required. For settling velocity, it is common to invoke Stokes Law, which can account for a variety of sediment properties, including density and shape.

For resuspension, no similar equation applies. The resuspension velocity is the characteristic velocity of turbulent entrainment from the bed. For an initial order-of-magnitude estimate, the turbulent velocity can be assumed equal to the shear velocity, commonly denoted as u_* and given by the following equation:

$$u^* = \frac{\tau_o}{\rho}^{1/2} \qquad \text{(A4-69)}$$

where

u^* = shear velocity (L/T)
τ_o = shear stress at bed (M/LT^2)
ρ = water density (M/L^3)

In steady uniform flowing streams, an expression for u_* is

$$u_* = (gHS)^{1/2} \tag{A4-70}$$

where

g = gravitational acceleration (L/T^2)
H = water depth (L)
S = channel slope

If the slope is not known, a rough rule of thumb is that the shear velocity is one-tenth (1/10) of the mean stream velocity. In an estuary, where tidally-induced currents are important, u_* can be approximated as 0.1 times the sum of the root-mean-square tidal velocity and the freshwater flow induced velocity.

The sedimentation velocity is the rate of change in contaminated bed thickness H_2 and can be positive or negative. If conditions in the bed are assumed uniform, the sedimentation velocity depends on settling, resuspension and compaction as follows:

$$V_d = \frac{dH_2}{dt} = \frac{m_1}{m_2} V_s - V_u - \frac{H_2}{m_2} \frac{dm_2}{dt} \tag{A4-71}$$

Given the uncertainty in estimating terms in this equation, the approach used (following O'Conner and Mueller, 1981) specifies V_d rather than trying to estimate V_d with this equation. In lieu of actual data, they suggest that in many natural systems, V_d is positive and on the order of 1 cm/year.

A4.3.2. Rate Coefficient for Dissolved Transport Across the Bed. Dissolved transport from or to the bed can be the result of a variety of processes, including:

- diffusion in the pore water space
- desorption at the interface

- migration associated with organisms moving through and mixing the sediments (bioturbation)
- physical processes mixing the sediments or inducing flow within the sediments

Diffusion in the water column is usually large relative to that in the pore water space and is therefore not normally a limiting process. Because of the difficulty separating the effects of the above processes, the dissolved transport rate coefficient is more an empirical than a theoretical coefficient.

Where molecular diffusion in the pore water space is important, the transport coefficient is given by the following:

$$K_b' = D_e\ \theta^{4/3}/\phi\delta \qquad \text{(A4-72)}$$

where

K_b' = bed transport coefficient (L/T)
D_e = effective molecular diffusivity (L^2/T)
δ = diffusive sublayer thickness (L)
ϕ = tortuosity of bed sediments
θ = porosity of bed sediments

Tortuosity is difficult to measure directly but can be measured indirectly based on electrical resistivity F (Ullman and Aller, 1982) as follows:

$$\phi^2 = \theta F \qquad \text{(A4-73)}$$

They found for surficial marine sediments that F correlated with porosity according to:

$$F = 1/\theta^m \qquad \text{(A4-74)}$$

where m ranged between 2 and 3.

The effective molecular diffusivity is used in equation A4-72 because, for hydrophobic chemicals, movement in pore water is highly retarded by sorption such that the effective molecular diffusivity is given by (Fisher et al., 1983):

$$D_e = \frac{D_o}{1 + k_d'} \qquad (A4\text{-}75)$$

where D_o is the molecular diffusivity for ions in free solution and k_d', the dimensionless distribution coefficient, is given by the following:

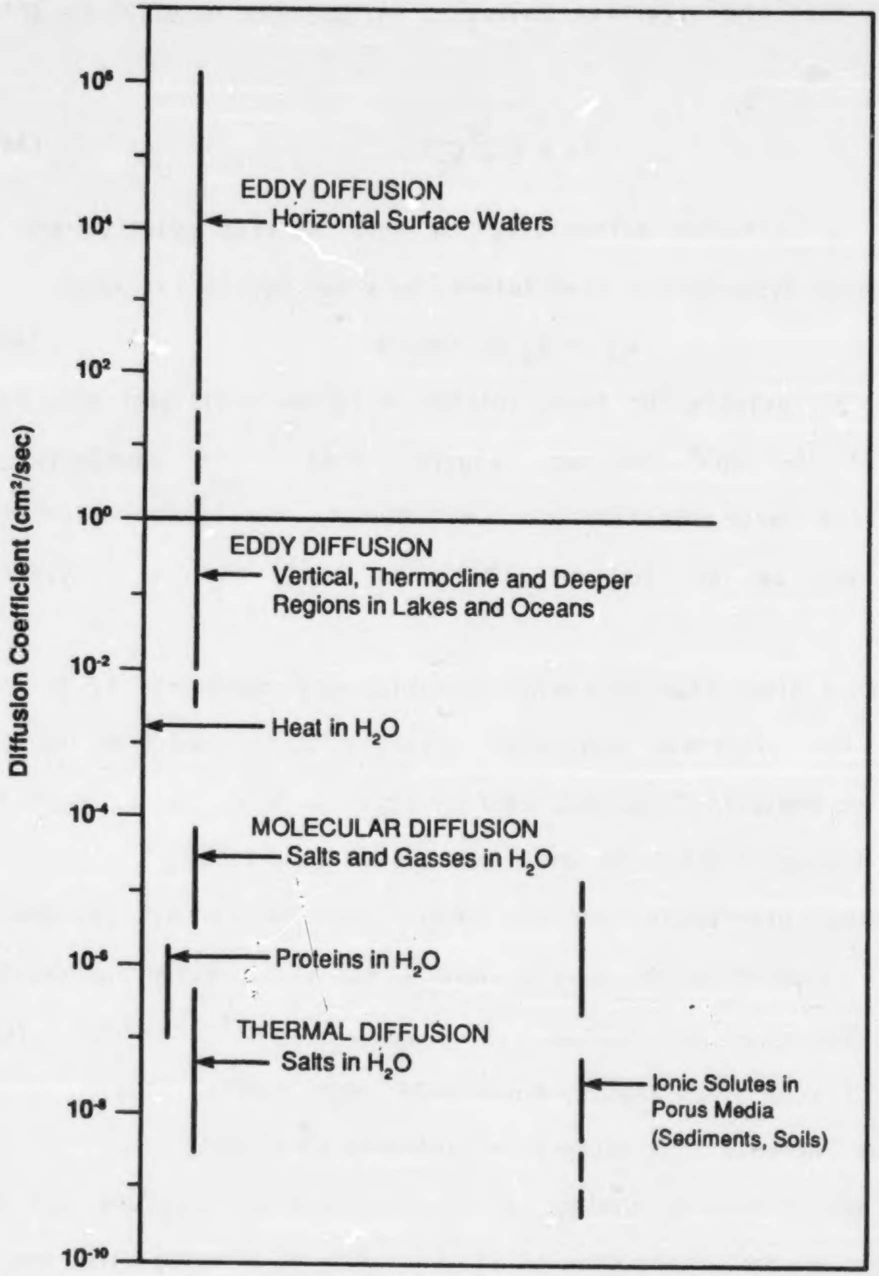
$$k_d' = k_d \, B \, (1-\theta)/\theta \qquad (A4\text{-}76)$$

The molecular diffusivity for ionic solutes in porous media generally varies between 10^{-10} to 10^{-5} cm^2/sec (Figure A4-8). For chemicals like PCBs which have large distribution coefficients, the effective molecular diffusivity may be as low as 10^{-14} to 10^{-11} cm^2/sec (Fisher et al., 1983).

When factors other than molecular diffusion are important, it is recommended that the effective molecular diffusivity in equation A4-72 be replaced by an empirical apparent diffusivity. This is the approach taken in the toxic transport model TOXIWASP (Ambrose et al., 1983).

As mentioned previously, another factor that may affect transport is bioturbation. Robbins et al. (1979) found that bioturbation increased the apparent diffusivity of Cesium 137 from 6.3×10^{-10} cm^2/sec for a control to 1.4×10^{-7} cm^2/sec. Karickhoff and Morris (1985) reported a 4- to 6-fold increase in transport in sediments with worms.

Induced advection and mixing of the sediment by pressure and shear forces created by the interaction of the bed with the flowing water can also enhance transport. According to Thibodeaux (oral communication, 1985), equation A4-72 may be suitable for quiescent lakes, but in more dynamic systems, like streams and estuaries, the actual transfer rates may be much larger than that predicted using the effective molecular diffusivity.



Source: Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling, Bowie et. al. EPA/60C/3-85/040 1985.

FIGURE A4-8

Diffusion Coefficients Characteristic of Various Environments

Savant et al. (1985), on the basis of laboratory and numerical experiments, show that circulation is induced in a bed having a wavy interface. They cite Peclet numbers (a measure of the importance of advective relative to diffusive effects) of 100-1000 which suggest that transport is advective rather than diffusive. For Peclet numbers in this range, the ratio of apparent diffusivity to the effective molecular diffusivity may be in the range of 10-100 (p. 392, Freeze and Cherry, 1979).

When estimating a value of the transport coefficient K_b' from equation A4-72, the various inputs required should be selected to yield a conservative (higher) value.

A4.3.3. Longitudinal Dispersion Coefficients. This section relies, to a large extent, on the excellent discussion on mixing in rivers and estuaries given in Fischer et al. (1979). The reader should consult this source for additional detail.

A4.3.3.1. STREAMS -- An estimate of the longitudinal dispersion coefficient is required for the event loading (Case 2). Longitudinal dispersion in streams and rivers is caused primarily by lateral and vertical diffusion in a nonuniform velocity (advective) field. A variety of irregularities in channel geometry (e.g., bends) contribute to this nonuniformity. A second mode of dispersion results from exchange between the main channel and ponds or side arms (dead zones). For example, in slug release dye tests, the long recession limb of the dye concentration is caused by slow release from dead zones.

Fischer et al. (1979) give the following equation for estimating dispersion in rivers in the absence of dead zones.

$$E = 0.011\, U^2\, W^2/du_* \qquad \text{(A4-77)}$$

where

E = longitudinal dispersion coefficient (L^2/T)
U = current speed (L/T)
W = width of river (L)
d = depth of river (L)
u_* = shear velocity (L/T)

The shear velocity can be estimated from the stream slope using equation A4-69 as discussed previously; or, in the absence of slope data, an order-of-magnitude estimate is that u_* is one-tenth of the mean current speed. Table A4-3 abstracted from Rutherford (1981) gives some measured values of longitudinal dispersion in open channels.

A4.3.3.2. ESTUARIES -- Longitudinal dispersion in estuaries is more complex than in rivers because of the effects of tides and stratification. Factors affecting dispersion include oscillatory shear flow dispersion, residual tidal circulation, tidal trapping and gravitational or density driven circulation.

Fischer et al. (1979) showed that shear flow dispersion will be a maximum if the tidal period is similar to the time required for cross-sectional mixing. Even then the maximum dispersion coefficient for shear flow only is estimated to be ~60 m^2/sec, much less than can occur in large rivers (see Table A4-3). For a narrow estuary where the cross-section mixing time is low, their results show that the dispersion coefficient is ~5% of the maximum value. For a wide estuary, the coefficient is ~13% of the maximum value. These values may be used as first estimates in the methodology which applies to constant density portions of estuaries.

Residual tidal circulation reflects the asymmetry in the tidal currents caused by irregular bathymetry and coreolis forces. Examples of residual tidal circulation are preferential ebb and flood channels. Tidal trapping is the effect of side embayments and small branching channels which exchange

TABLE A4-3

Summary of Reported Longitudinal Dispersion Coefficients for Rivers†

Channel	Depth d (cm)	Width w (m)	Sheer Velocity u* (cmxs^{-1})	Discharge Q (m^3.s^{-1})	Dispersion Coefficient E m^2.s^{-1}	Dispersion Coefficient E/du*
Yuma Mesa A Canal	345	--	3.45	--	0.76	8.6
Chicago Ship Canal	807	48.8	1.91	--	3.0	20
River Derwent	25	--	14.0	--	4.6	131
Monocay River	32.2	35	4.35	2.4	4.7	332
	44.5	36.5	5.12	5.2	13.9	610
	87.6	47.6	7.18	18.4	37.2	591
Green-Duwamish River	110	20	4.9	--	6.5-8.5	120-160
Concite River	25.5	12.5	4.42	1.0	7.0	620
	41.2	15.9	5.61	2.4	13.9	600
Clinch River	58	36	4.9	6.8	8.1	280
	84	47	6.7	9.2	14	235
	210	53	10.7	51	47	210
	210	60	10.4	85	54	245
Antietam Creek	28.7	15.9	6.16	2.0	9.3	390
	51.6	19.8	17.11	4.4	16.3	440
	70.6	24.4	8.32	8.9	25.6	435
Elkhorn River	30.1	33	4.64	4.3	9.3	666
	42.0	50.9	4.68	10.0	20.9	1063
Powell River	85	34	5.5	4.0	9.5	200

TABLE A4-3 (cont.)

Channel	Depth d (cm)	Width w (m)	Sheer Velocity u* ($cmxs^{-1}$)	Discharge Q ($m^3.s^{-1}$)	Dispersion Coefficient E $m^2.s^{-1}$	E/du*
Copper Creek	49	16	8.0	1.5	9.5	245
	40	19	11.6	13.7	9.9	220
	49	16	8.0	1.5	20	500
	85	18	10.0	8.5	21	250
Coachella Canal	156	24	4.3	26.9	9.6	140
Lucas Creek	--	--	--	--	10	--
Fraser Estuary	--	--	2.7-7.0	--	10.7-12.7	18-38
Bayou Anacoco	41.5	19.8	4.51	2.4	13.9	743
	93.7	25.9	6.78	8.2	32.5	511
	92.1	36.6	6.72	13.5	39.5	638
	80.8	13.4	8.11	4.0	13.9	212
Muddy Creek	120	19.5	9.88	10.6	32.5	274
John Day	56	24	14.0	14.2	13.9	177
	246	34	18.1	69	65	146
Sacramento River	400	--	5.1	--	15	74
South Platte River	400	--	5.1	--	16.2	510
Amite River	80.7	36.6	6.95	8.6	23.2	414
	80.1	42.4	6.92	14.2	30.2	545
Manawatu River	1.0	25	10	26	26-45	260-450

TABLE A4-3 (cont.)

Channel	Depth d (cm)	Width w (m)	Sheer Velocity u* (cmxs^{-1})	Discharge Q (m^3.s^{-1})	Dispersion Coefficient	
					E m^2.s^{-1}	E/du*
White River	54.7	67	4.40	12.8	30.2	1255
Chattahoochee River	113	65.5	7.58	30	32.5	379
Waikato River	200-300	70-130	5.4-5.8	160	33-70	240-510
average	250	100	5.5	160	50	360
Nooksack River	76	64	--	33	34.9	--
	293	86	53.1	300	153.4	98.6
Sabine River	98.5	35	4.17	7.4	39.5	961.7
	204	104	5.47	119	316	2832
	475	127	8.36	389	670	1687
Wind/Bighorn River	97.7	67	11.2	58	41.9	383
	216.5	68.6	16.6	231	163	454
Susquehana River	135	203	6.51	106	92.9	1057
Yadkin	233	70	10.0	71	112	481
	385	71.6	12.9	213	260	524
Mississippi	--	--	--	10,310	185-232	--
	--	--	--	22,600	650-700	900
Missouri River	223	183	6.61	380	465	3155
	270	200	7.4	--	1500	7500
	356	201	8.36	913	837	2812
	311	197	7.81	935	892	3672

†Source: Rutherford, 1981

contaminant with the main channel at different rates depending on the tidal cycle. Gravitational or density driven circulation is the net circulation caused by the density difference between the river inflow at the head of (or along) the estuary and the sea at the mouth of the estuary. In stratified estuaries, the classical estuarine circulation is downstream near the surface and upstream at depth.

Because these effects are site specific, the best available method to estimate the longitudinal dispersion coefficient is from salinity data as follows:

$$E = \frac{Us}{\frac{\partial s}{\partial x}} \qquad \text{(A4-78)}$$

where:

E = longitudinal dispersion coefficient (L^2/T)
s = salinity (M/L^3)
U = freshwater velocity (L/T)
x = longitudinal coordinate (L)

Field measurements used to estimate the salinity should take into account spatial variability of the salinity across the channel and the changes in salinity with the tide. Results will differ depending on the approach. Fischer et al. (1979) give values for some observed longitudinal dispersion coefficients. They ascribe the lower values (in the range of 10-50 m^2/sec) to constant density reaches for which the methodology applies.

A4.3.4. Partition or Distribution Coefficients. Partition coefficients are required to establish the dissolved/adsorbed equilibrium in the water column and in the bottom sediments. In the development of the methodologies, allowance has been made for different distribution coefficients in the bed versus the water column. Baes and Sharp (1983) summarize statistics of the distribution coefficients for various contaminants including metals for which the data exhibit a large range.

A4.3.5. BED SEDIMENT PROPERTIES -- Bed sediment properties used in the analyses are solids density and porosity. The solids density of the mixture of soil and sludge will be less than the soil density (2.65 $\mathrm{gm/cm^3}$ for most mineral soils) a factor that would be important in resuspension. However, in the methodology resuspension is specified by a velocity and consequently, a solids density of 2.65 $\mathrm{gm/cm^3}$ is adequate.

The porosity of surficial sediments generally ranges between 0.6 and 0.9 and in lieu of data, a mid-range value would be adequate.

A4.4. EXAMPLE CALCULATIONS

A4.4.1. Streams. For easy reference, the definitions and values of the input parameters for the example calculations are provided in Table A4-4.

A4.4.1.1. CASE 1, CONSTANT LOADING -- Use equation A4-16 to calculate the concentration:

$$CTi\ (x) = CTi\ (0)\ \exp\ - \frac{K_{Si}}{U} + \frac{1}{D}\ x \qquad \text{(A4-16)}$$

where $K_{S1} = V_s/U$ and $D^2 = WS\ (0)$ is the watershed area for the stream position on the SMA boundary (X=0).

For the example problem (see Table A4-4)

$$K_{S1} = V_s/H_1$$

$$= \frac{2.27 \times 10^{-3}\ \mathrm{cm/sec}}{100\ \mathrm{cm}}$$

$$= 2.27 \times 10^{-5}\ 1/\mathrm{sec}$$

$$D^2 = 2000\ \mathrm{ha}$$

$$D = 4472\ \mathrm{m}$$

$$U = 1\ \mathrm{m/sec}$$

$$x = 10{,}000\ \mathrm{m}$$

$$C_{Ti}\ (10{,}000) = 1.93\mathrm{x}10^{-5}(\mathrm{mg}/\ell)\ \exp\ - \frac{2.27 \times 10^{-5}}{1} + \frac{1}{4472}\ 10{,}000$$

$$= 1.6\mathrm{x}10^{-6}\ \mathrm{mg}/\ell$$

TABLE A4-4

Input Parameter Definitions and Values for the Streams Example Problem

---

M = Long-term average chemical mass loading rate, 7.4×10^{4} kg/year

M_o = Event chemical mass loading, 219.6 kg

E_o = Total event solids mass loading, 1.2×10^{4} mt

Q_f = Stream flow rate, 10 m^3/sec (3.15×10^{11} ℓ/year)

V_1 = Stream flow volume over the period of the event (stream flow rate, Q, times the storm duration, R_t), 2.16×10^{5} m^3

x = Distance downstream from the SMA, 10,000 m

U = Stream velocity, 1 m/sec

V_s = Settling velocity, 2.27×10^{-3} cm/sec

H_1 = Stream depth, 100 cm

WS(o) = Area of watershed for receiving water at the location of the site -- 2000 ha

e_s = Bulk density of stream bed, 1.6 gm/cm^3

θ = Porosity of stream bed, 0.15

Kd = Distribution coefficient, Benzene -- 7.4×10^{-3} ℓ/kg

This is well below the RWC and, therefore, no further Case 1 analysis is required.

A4.4.1.2. CASE 2, EVENT LOADING --Use equation A4-16 to calculate the stream concentration for the analysis.

$$C_{Ti,MAX} = C_{Ti,0} \exp(-K_1\ t')$$

where $K_1 = K_{S1} + U/D$ and $t' = x/U$

For the desired benzene concentration

$$C_{Ti,MAX} = 2.36\times10^{-3}\ \text{mg}/\ell \exp[(-2.46\times10^{-4}\ \ell/\text{sec})\ (10^4\ \text{sec})]$$

$$= 2.01 \times 10^{-4}\ \text{mg}/\ell$$

The calculations show that the benzene concentration in the stream drops below the RWC at a distance of 10 km downstream. Thus, no further analysis is necessary.

A4.5. REFERENCES

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APPENDIX 5

DISTRIBUTION COEFFICIENTS

Distribution coefficients are required to determine how a contaminant will partition itself between the soil particles and the soil water. The distribution coefficient, Kd, is defined as:

$$Kd = S/C \qquad (A5\text{-}1)$$

where S = concentration of contaminant on soil (mg/kg)

C = concentration of contaminant in water (mg/ℓ)

The concept of Kd is a gross simplification of attenuation of inorganic contaminants in soil. Precipitation chemistry is an important factor in attenuation over and above adsorption and exchange. Precipitation does not yield a solution concentration in proportion to the mass of contaminant in the system. As a consequence, the use of a Kd is most valid at low contaminant concentration levels where contaminants do not exceed solubility thresholds.

For organics, the Kd concept is more broadly useful because adsorption accounts for most soil attenuation. In the case of organics, Kd is calculated from the distribution as a function of organic carbon content of the soil (K_{oc}) and the fraction of soil (f_{oc}) consisting of organic matter as follows:

$$Kd = (K_{oc})(f_{oc}) \qquad (A5\text{-}2)$$

If values for K_{oc} have not been determined experimentally, equations are available that relate K_{oc} to octanol-water partition coefficient data -- (K_{ow}) or solubility.

Table A5-1 is provided to assist the analyst in selecting Kd values for contaminants of interest. Values for inorganic contaminants were derived from the literature for sandy and sandy-loam soils. No difference is anticipated between unsaturated and saturated soils. The analyst should select the soil condition most closely matched to soils found on site for selection of the Kd.

For organic contaminants, the Kd is a function of organic content in soil. As a consequence, the analyst has two options:

1. If the organic content of the soil on site is known, the K_{oc} value should be selected from Table A5-1 and the Kd calculated from Equation A5-2.
2. If the organic content of the soil on site is not known, the soil classification should be matched with those soil types provided in Table A5-1 and the associated Kd value selected.

It is assumed that subsoils in the aquifer will not have organic matter and, therefore, the Kd for organics in the saturated zone is equated to zero. This is conservative in that research suggests that at low organic levels (i.e., <0.1%), organics interact with clay minerals. However, these interactions are not well understood and no means of prediction is currently available. Therefore, retention in the saturated zone is not considered at this time.

Whenever specific Kd values are available for the on-site soil, they should be employed in place of the values provided in Table A5-1. Use of such data should be accompanied by detailed documentation on how they were derived.

TABLE A5-1

Distribution Coefficients for Selected Contaminants

Contaminant	K_{oc} [(mg/kg$_{oc}$)/(mg/ℓ)] (organics only)	Kd - Distribution Coefficient [(mg/kg)/(mg/ℓ)]							Reference
		Soil Type	Unsaturated Sand	Unsaturated Sandy Loam	Unsaturated Silty Loam	Unsaturated Silty Clay Loam	Saturated Sand	Saturated Sandy Loam	
		Organic Fraction	0.0001	0.005	0.001	0.13	0.0	0.0	
Aldrin	4.6×10^{3}		0.46	23	4.6	59	0.0	0.0	Dawson et al., 1980
Arsenic	NA		5.86	19.4			5.86	19.4	U.S. EPA, 1985a
Benzene	74		7.4×10^{-3}	0.37	7.4×10^{2}	0.96	0.0	0.0	U.S. EPA, 1985a
Benzo(a)anthracene	1.38×10^{6}		138	6900	1380	1.8×10^{4}	0.0	0.0	Lyman et al., 1982
Benzo(a)pyrene	6.3×10^{5}		63	3.2×10^{3}	630	8.2×10^{4}	0.0	0.0	U.S. EPA, 1985a
Bis (2-ethyl hexyl) phthalate	7244		0.72	36	7.2	94	0.0	0.0	U.S. EPA, 1985a
Cadmium	NA		14.9	423			14.9	423	U.S. EPA, 1985a
Carbon Tetrachloride	650		0.065	3.25	0.65	84.5	0.0	0.0	U.S. EPA, 1985a
Chlordane	1.7×10^{5}		17	850	170	2.2×10^{4}	0.0	0.0	U.S. EPA, 1985a
Chloroform	280		0.028	1.4	0.28	36.4	0.0	0.0	U.S. EPA, 1985a
Chromium	NA		16.8	56.5			16.8	56.5	U.S. EPA, 1985a
Cobalt	NA		1.94	8.81			1.94	8.81	U.S. EPA, 1985a
Copper	NA		41.9	92.2			0.0	92.2	U.S. EPA, 1985a

TABLE A5-1 (cont.)

		Kd - Distribution Coefficient [(mg/kg)/(mg/ℓ)]							
Contaminant	K_{oc} [(mg/kg$_{oc}$)/(mg/ℓ)] (organics only)	Soil Type	Unsaturated Sand	Unsaturated Sandy Loam	Unsaturated Silty Loam	Unsaturated Silty Clay Loam	Saturated Sand	Saturated Sandy Loam	Reference
		Organic Fraction	0.0001	0.005	0.001	0.13	0.0	0.0	
Cyanide	NA		0.0	0.0			0.0	0.0	U.S. EPA, 1985a
DDT/DDE/DDD	5×10^6		500	2.5×10^4	5×10^3	6.5×10^5	0.0	0.0	U.S. EPA, 1985a
2,4-Dichlorophenoxy-acetic acid	20		2×10^{-3}	0.1	2×10^{-2}	0.26	0.0	0.0	Dawson et al., 1980
Dieldrin	900		9.1×10^{-2}	4.5	9.1×10^{-1}	12	0.0	0.0	Dawson et al., 1980
Dimethylnitrosamine	0.04		4×10^{-6}	2×10^{-4}	4×10^{-5}	5.2×10^{-3}	0.0	0.0	U.S. EPA, 1985a
Fluoride	NA		0.0	0.0	0.0	0.0	0.0	0.0	Estimate based on solubility of fluoride salts
Heptachlor	3164		0.3	46	3	39	0.0	0.0	Dawson et al., 1980
Hexachlorobenzene	3900		0.4	20	4	52	0.0	0.0	Dawson et al., 1980
Hexachlorobutadiene	7595		0.8	38	8	104	0.0	0.0	Dawson et al., 1980
Iron	NA		15				15		O'Melia and Strumm, 1967
Lead	NA		234	597			234	597	U.S. EPA, 1985a
Lindane	1080		0.1	5.4	1.0	1.3	0.0	0.0	U.S. EPA, 1985a
Malathion	1800		0.18	9.0	1.8	2.3	0.0	0.0	U.S. EPA, 1985a

TABLE A5-1 (cont.)

Contaminant	K_{oc} [(mg/kg$_{oc}$)/(mg/ℓ)] (organics only)	Kd - Distribution Coefficient [(mg/kg)/(mg/ℓ)] Soil Type	Unsaturated Sand	Unsaturated Sandy Loam	Unsaturated Silty Loam	Unsaturated Silty Clay Loam	Saturated Sand	Saturated Sandy Loam	Reference
		Organic Fraction	0.0001	0.005	0.001	0.13	0.0	0.0	
Mercury	NA		322	580			322	580	U.S. EPA, 1985a
Methylene bis (2-chloroaniline)	9120		0.91	46	9.1	120	0.0	0.0	U.S. EPA, 1985b
Methylene chloride	10		1×10^{-3}	5×10^{-2}	1×10^{-2}	0.13	0.0	0.0	U.S. EPA, 1985a
Methyl ethyl ketone	24		3.4×10^{-3}	0.17	3.4×10^{-2}	0.44	0.0	0.0	U.S. EPA, 1985b
Molybdenum	NA		8.58	43.4			8.58	43.4	U.S. EPA, 1985a
Nickel	NA		12.2	58.6			12.2	58.6	U.S. EPA, 1985a
Nitrate	NA		0.0	0.0	0.0	0.0	0.0	0.0	Estimate based on solubility of nitrate salts
Pentachlorophenol	1.26×10^{4}		1.26	63	13	169	0.0	0.0	Dawson et al., 1980
Phenanthrene	2.3×10^{4}		2.3	115	23	300	0.0	0.0	U.S. EPA, 1985a
Phenol	16.6		1.6×10^{-3}	0.08	1.6×10^{-2}	0.22	0.0	0.0	U.S. EPA, 1985a
Polychlorinated biphenyls	3.2×10^{6}		320	1.6×10^{4}	3.2×10^{3}	4.2×10^{5}	0.0	0.0	U.S. EPA, 1985a
Selenium	NA		5.91	14.9			5.91	14.9	U.S. EPA, 1985a
Tetrachloroethylene	618		0.062	3.1	0.62	80	0.0	0.0	U.S. EPA, 1985a

TABLE A5-1 (cont.)

Contaminant	K_{oc} [(mg/kg$_{oc}$)/(mg/ℓ)] (organics only)	Kd - Distribution Coefficient [(mg/kg)/(mg/ℓ)]							Reference
		Soil Type	Unsaturated Sand	Unsaturated Sandy Loam	Unsaturated Silty Loam	Unsaturated Silty Clay Loam	Saturated Sand	Saturated Sandy Loam	
		Organic Fraction	0.0001	0.005	0.001	0.13	0.0	0.0	
Toxaphene	960		9.6×10^{-2}	4.82	0.96	12	0.0	0.0	U.S. EPA, 1985a
Trichloroethylene	198		2.0×10^{-2}	0.99	0.2	2.6	0.0	0.0	U.S. EPA, 1985a
Tricresyl Phosphate	840		0.08	4.2	0.8	10	0.0	0.0	Lyman et al., 1982
Vinyl Chloride	134		0.013	0.65	0.13	17	0.0	0.0	U.S. EPA, 1985a
Zinc	NA		12.7	939			12.7	939	U.S. EPA, 1985a

NA = Not applicable

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